RESOURCE DEPLETION AND MANAGEMENT IN RURAL ECONOMIES:

GROUNDWATER IN TWO TEXAS WATERSHEDS

by

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ABSTRACT

The Palo Duro and Double Mountain Fork Regions of Texas include counties that cover sub-basins of the Ogallala Aquifer. These regions rely on the Ogallala Aquifer for water. As concern grows over the diminishing availability of groundwater, policies such as caps on water use are put in place to conserve water. These policies raise concerns over their impacts on employment, markets, the welfare of different income groups, and impacts across political boundaries.

This study analyzed policy impacts in the Palo Duro and Double Mountain Fork Regions in Texas. A computable general equilibrium model (CGE) was developed to assess impacts on the economy by combining economic theory with real economic data. Data were collected for water use, land (including agricultural land use and production), and Impact Analysis for Planning (IMPLAN) sectors. These data were compiled into a social accounting matrix (SAM) to represent the flow of economic transactions in each of the two regions and balanced using the RAS procedure. The General Algebraic Modeling System (GAMS) was used to compile the data and create the CGE model. Land and water were added to the model as factors of production.

Importantly, a CGE model of this kind has never been incorporated into water policy analysis for this area in Texas. Rather, most studies have only utilized a modified IMPLAN model to measure direct, indirect, and induced impacts of economic output, value-added, and employment within a regional economy. The CGE model makes it

possible to further evaluate factors such as employment impacts, price impacts, and other economy-wide implications of various policy scenarios.

Comparisons were made between the impacts of different policy scenarios within the two regions. The scenarios analyzed included a baseline scenario without any policy implementation along with projected saturated thickness depletion after 50 years, a water reduction policy scenario, a land reduction scenario, and technology advancement scenario. The results of the study indicate that the projected saturated thickness depletion scenario with the land reduction policy scenario had the biggest impact on the overall economy in both the Palo Duro and Double Mountain Fork regions. In the Palo Duro Region, the projected saturated thickness scenario with the water reduction scenario mitigates some of the negative changes to GDP through policy, while the projected saturated thickness depletion scenario with the technology change scenario mitigates some of the negative changes in the Double Mountain Fork region. There is need for future research as these scenarios do not account for the negative impacts to producers such as costs and loss of production.

This information is useful for policymakers to base their decisions on in order to keep the regional economy viable while saving water. In addition, the creation of the foundational CGE modeling procedure will be beneficial in evaluating alternative scenarios in the future as water levels and political dynamics in the region change over time. This study had several limitations including how detailed the model could be. Future research should focus on nested production functions and combining this model with other economic models to improve the abilities of this model.

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CHAPTER 1: INTRODUCTION

The United States' Great Plains is the location of the Ogallala Aquifer with its most saturated zones spanning from Nebraska to the panhandle of Texas and Oklahoma into southwestern Kansas. The Ogallala Aquifer covers 173,000 square miles and is the largest freshwater aquifer in the United States, Figure 1. As water availability is drastically reduced and recharge is limited to deep percolation, concern grows over future availability and allocation of the resource. It is estimated that rainfall today could take 1,000 years or longer to reach and recharge the aquifer (Brauer, et al., 2017).

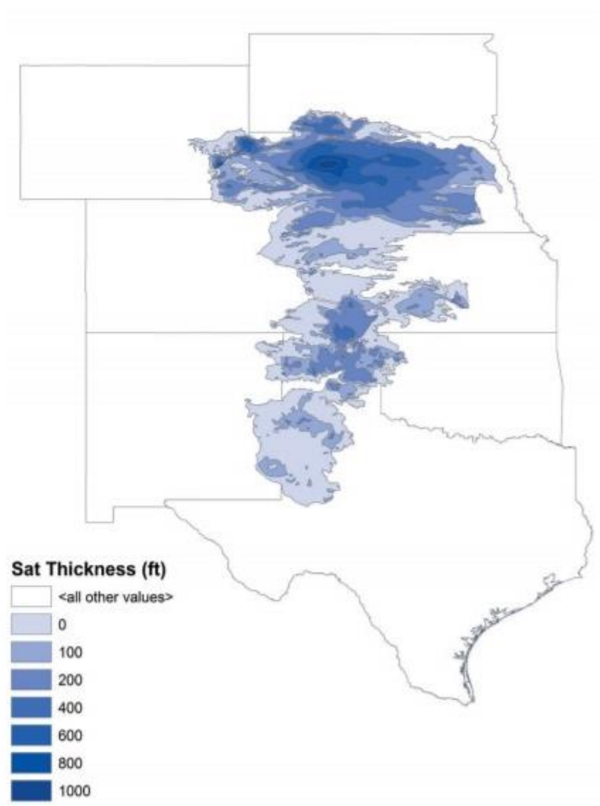

Figure 1. The saturation levels and location of the Ogallala Aquifer.

Source: Brauer, et al., 2017

Funding and congressional actions since the early 2000s have helped create initiatives like the Ogallala Aquifer Program (OAP) and the Ogallala Water Coordinated Agriculture Project (OWCAP) to allow funding for research to help determine a direction for future water policy on the Ogallala Aquifer. It is important for policymakers to have access to sound data when making decisions that could affect the availability of water in the Ogallala Aquifer (Brauer, et al., 2017).

Agricultural output in the Great Plains relies heavily on water from the Ogallala Aquifer. During the post-World War II era, there was a great increase in irrigated cropland acreage. Irrigated acreage reached seven million acres by 1959 and 13 million acres by 1978. In the 1980s, irrigated acres declined by roughly 20 percent as withdrawal rates from the Ogallala Aquifer were exceeding rates of recharge. High withdrawal rates and low rates of recharge resulted in lower well yields, deeper water tables, and reduced saturated thickness. Even with the decline in irrigated acres, approximately 90 percent of groundwater withdrawals from the Ogallala Aquifer are accounted for by irrigated cropland acres. Areas with irrigated acres historically see one to three feet of depletion annually. Programs were developed with a focus on water management strategies and technologies to reduce water withdrawals by 20 percent in 2020 from the levels reported in 2012 (Brauer, et al., 2017).

More recently, irrigated crop production accounted for 98.2 percent of water use with the other 1.8 percent being used by livestock operations in 2014. For several decades water use in the Southern Ogallala Region has exceeded the recharge rate leading to a decline in the aquifer. As underground water supplies continue to decline, irrigated cropland is expected to fall. The decline in irrigated acreage is likely to increase production of more drought-tolerant dryland crops such as cotton (Amosson, et al., 2015).

There is great interest in how policy changes will impact resource allocation. Historically, agriculture has been constrained by the scarcity of water. Individuals generally see little effect on water levels because they do not pay the social cost of water extraction. Regulation on water use is rarely strict, although in some cases well metering and limitation of new wells have been explored as a way to slow the depletion of the aquifer, and most state laws do not allow wastage. Many factors come into play concerning policy (Hornbeck and Keskin, 2014). Federal tax codes allow farmers who extract water for irrigation to depreciate the value of water decline from the aquifer. Cost depletion deductions are given to farmers who can demonstrate that ground water is depleting and the rate of recharge is low enough that water is lost for the taxpayer and any immediately succeeding generations (Internal Revenue Service, 2020).

Technology has advanced so that farmers can irrigate on a larger scale and reallocate their land for high-value water-intensive crops, however, this has led to an increase in drought sensitivity. In non-Ogallala counties, there is a higher tolerance to drought, but these counties also see lower agricultural land values. Production has changed over time with the help of conservation programs to lessen the effects of declining water availability so that Ogallala counties are about as sensitive to drought as non-Ogallala counties (Hornbeck and Keskin, 2014).

Texas is the only state to operate under the common-law rule of capture under which the landowner owns the water beneath their land and has the right to pump the water beneath their land. The rule of capture is commonly referred to as the “law of the biggest pump”, indicating that landowners face incentives to pump groundwater before their neighbors do. The rule has been modified to prevent waste, subsidence, and harmful or malicious use (Texas Water Code § 36.002).

Although the rule of capture alone may lead to increased use in some instances, legislative actions have been taken to help conserve and protect groundwater resources in Texas. The state government has begun to exercise its right to control groundwater resources through a change to the Texas Constitution, known as the conservation amendment. The amendment provides for the creation of groundwater conservation districts (GCDs) to manage natural resources (Texas Water Code § 36.0015). As a result, Texas has witnessed the formation of groundwater management areas (GMAs) to facilitate planning between GCDs within a common area that share the resource. In 2005, GMAs were required to adopt desired future conditions (DFCs), which amount to quantifiable goals for the future state of the resource (Mace et al. 2006). The individual conservation districts are then tasked with developing their own plans for meeting the applicable DFC.

The most common DFC in the Texas High Plains is the 50/50 rule, meaning that 50 percent of the current aquifer level remains in 50 years. Implementation of this DFC has not been easy and different conservation districts have taken different approaches. For example, the North Plains Groundwater Conservation District has set a limit for allowable annual use of 1.5 acre-feet of water per acre per year. Adjustments may also be made to the limit in order to reach the targeted DFC. In this particular district, the DFC is set at 40/50 for counties with higher historical water use and at 50/50 for all other counties (North Plains Groundwater Conservation District, 2015). In the High Plains

Underground Water Conservation District, agricultural producers must adhere to the allowable production rate of 1.5 acre-feet per contiguous acre per year. A contiguous acre includes acreage within the district along with any abutting acreage (physically touching, including corners) or non-abutting acreage (if the acreage is connected by a common water pipeline system) (High Plains Underground Water Conservation District, 2015).

Since the early 1900s, Computable General Equilibrium (CGE) modeling has been used as a tool to analyze and quantify the impact of specific policies on resource allocation and income distribution in market economies. The "bridge" perspective has been credited for the widespread use of CGE modeling as it links economic theory and applied policy research to effectively explain real-world economies. This perspective suggests that CGE modeling uses economic theory instead of merely testing economic theory. As technology advanced, CGE models were used on a greater scale. Faster computers and better software improved the accuracy and time needed to create the model. There are several characteristics found in CGE models that make them useful. One characteristic is that they are multi-sector models dependent on real-world data of one or more regional economies. Markets for financial assets are not included in CGE models as they determine real prices and exchange rates instead of nominal prices and exchange rates. Even though they contain large amounts of data, most are fairly aggregated. Other characteristics include exhibiting constant returns to scale, profit maximization behavior of households and firms is assumed, product and factor markets are assumed to be competitive, and technical coefficients are flexible and determined by relative prices (Bergman, 2005).

The purpose of this study was to develop a CGE model focused on estimating how changes in various agricultural production scenarios will impact other sectors of the economy and the magnitude of these effects in the rural economy. Two rural regions covering the sub-basins of the Ogallala Aquifer were the main focus of the study. Impacts to other sectors, labor market implications, local government finance, impacts of reduced water availability, and impact of policies in these regions were considered and simulated.

Specifically, the CGE model was utilized to compare four scenarios to the projected baseline scenario of the Ogallala Aquifer. Water, land, and technology were identified as three major factors that would impact agriculture and other sectors of the regional economy related directly and indirectly to agriculture. Thus, a baseline scenario including the current decline in saturated thickness of the Ogallala Aquifer as well as four scenarios (each including the expected saturated thickness depletion) were evaluated as follows:

- A baseline scenario without any policy implementation;
- A scenario simulating current projections of groundwater depletion;
- A scenario simulating a water use reduction policy;
- A scenario simulating reduced land availability; and
- A scenario simulating technology advancement where producers convert to more efficient irrigation systems.

CHAPTER 2: LITERATURE REVIEW

CGE models can be classified as static, dynamic, or quasi-dynamic models. When stock accumulation is included and forward-looking behavior of households and firms is assumed, the model should be considered “dynamic”. When a static model focuses on multi-period analyses, it should be considered “quasi-dynamic”. CGE models can also be classified as single-country, multi-country, and global models. In single-country models, there is more detail concerning sectors and household types as they are used to analyze country-specific policy issues and proposals. Multi-country and global models are less detailed in these areas and focus more on analyzing multi-lateral policies like free-trade agreements (Bergman, 2005).

One standard data structure for a CGE Model is a Social Accounting Matrix (SAM) with columns for expenditures and rows for receipts that gives a descriptive analysis of the structure of the economy. The SAM is read from column to row. A SAM must be supported by large amounts of statistical data from various resources. Often a SAM will have an imbalance when data is pulled from multiple resources such as national accounts, trade data, and input-output tables. Three things must be true to obtain an unbalanced SAM. First, data must be turned into a square matrix with expenditures and receipts corresponding to the columns and rows of the matrix, where the column and row sums must be equal. Second, the SAM must be comprehensive and portray all economic activities including consumption, production, accumulation, and distribution.

Third, the SAM must be flexible in the degree of desegregation and the emphasis on various parts of the economic system. To correct the imbalance, programs such as GAMS are often used to balance and estimate a SAM (Lee et al., 2014). In 2010, a study was conducted to evaluate the economic impact of productivity changes to aid policymakers' decisions when providing incentives to specific sectors to develop new technologies. The study focused on the interaction between households, private sectors, the local government, and the regional economy in Fort Collins, Colorado using data sources for employment, wages, land, capital, and various local taxes (Cutler and Davies, 2010).

Several simulations were run, focusing on an increase in labor productivity, an increase in the productivity of capital, and an increase in total factor production. An increase in total factor production created the most beneficial impact on the economy. The largest increase in real household income came from the high services sector consisting of medical, legal, business services, engineering services, and biotech. When labor productivity was increased, labor was substituted out and wages had downward pressure concerning workers seeking employment in other sectors or migrating out of town. Stimulation of further economic growth was shown to happen when increases in capital productivity increased the marginal product of labor causing households to migrate into the city. Increases in productivity in manufacturing and computer manufacturing resulted in the greatest increase in tax revenue per household (Cutler and Davies, 2010).

The majority of CGE models use large geographical study areas and significantly aggregate the data. The towns and regions that comprise these large areas are unique. Choosing a smaller geographical study area allows these unique qualities to arise and allows individual city governments to create policies that may vary substantially from the optimal policies for surrounding cities. When using a large study area, the resulting policies may not be fitting for every city in the study area (Schwarm and Cutler, 2003).

In 2003, a study was conducted to show how different the results can be from a CGE model for varying cities. The study collected data for employment, wages, land, and capital for the private sector and local government in Colorado using data sources such as Impact Analysis for Planning (IMPLAN), county assessors' data, and the Colorado Department of Labor. The data was organized into a SAM which was then balanced. The results showed the possibility of creating CGE models for areas of all sizes and proved that there can be substantial differences in important areas like relative wages, household migration, commuting, and land-use zoning between various cities. Studies with practically identical underlying structures can have significantly different effects to policy changes proving there is a need for analysis of smaller geographical areas. For example, the study looked at the Colorado towns of Fort Collins, Loveland, and Windsor. Wage differences, population differences, and differences in the opportunities for employment in these three towns show vesting different percentages of workers commuting in and out of each town. Fort Collins sees only 23.0 percent of workers commuting out of town while Loveland sees 51.7 percent and Windsor sees 79.1 percent of workers commuting out of their respective towns (Schwarm and Cutler, 2003).

This study was later extended using the same model to show the effects of an increase in manufacturing and a change in sales tax. Data was collected to represent the areas of interest for the extended study and again organized into a balanced SAM. While the study focused on different aspects of the economy, it resulted in the same conclusion that research can show vastly different effects between surrounding cities. As the demand for manufacturing exports increased, each of the three towns increased employment by 250 workers. This change created the smallest increase in households for Windsor but also the largest percentage increase in income. A significant decrease in unemployment was seen in all three towns proving that a large direct impact is not needed to create a noticeable effect on unemployment; however, migration and commuting are important factors to consider with unemployment rates. It is also important to consider real income. The consumer price index for Windsor increased by 0.24 percent, Loveland increased by 0.13 percent, and Fort Collins increased by 0.08 percent (Schwarm and Cutler, 2005).

The extended study also looked at the economic impact of sales tax for the three towns. When examining a 1 percent increase in sales tax, a fall in gross city product (GCP) by 0.37 percent in Loveland, 0.30 percent in Fort Collins, and 0.16 percent in Windsor resulted. Loveland experienced a larger downturn because they are the most dependent on sales tax-related sectors while Windsor is the least dependent on sales tax-related sectors. Indirect multiplier effects cannot be ignored as the study showed that the upper household income groups experienced a larger decrease in household income as they earn the largest percentage of capital and land income. Capital and land income fell at a greater rate than labor income in all three towns (Schwarm and Cutler, 2005).

In 2008, Philip Watson and Stephen Davies conducted a CGE study to model how population growth affected a fixed total supply of water in the South Platte River Basin of Colorado. An 18-sector CGE model was created in GAMS using IMPLAN county-level social accounts that were placed into SAM. Water was added to the model as a primary factor of production for the agricultural and municipal water sectors. Land was also added as a primary factor of production for all sectors. The GAMS CGE model consisted of 1,104 simultaneous equations based on the Washington State regional computable general equilibrium modeling system. This model was modified with additional equations to better represent water and land as primary production factors (Watson and Davies, 2011).

This study evaluated the effects of land and water taken out of extensive crop production to be used in other municipal and industrial sectors of the economy. From 2002 to 2030 there is expected to be a 5.7 percent transfer of water from agriculture to meet the demands of population growth in the South Platte River Basin of Colorado. Water from this transfer that was not used by municipal sectors would then be accessible for agricultural producers. Municipal water was expected to increase by 8.4 percent and agricultural water to increase by 10.4 percent. An alternative simulation was run to see the effects of restricting the transfer of water. In this scenario, municipal water was expected to increase by 25 percent or 16.6 percent more than the original scenario. The total real gross domestic product (GDP) of the alternative simulation was comparatively similar to the original simulation (Watson and Davies, 2011).

In 2012, a nested CGE model analysis was conducted to estimate how a reduction in the foreign-born labor supply would affect the state economy in Idaho. This study was based on the Washington-Idaho CGE model and run in GAMS. The model was modified to include a four-level nested production function to represent foreign and native labor classes split by education level. There were 14 aggregated sectors in the model with five primary factors of production including capital, foreign-born less educated labor, native-born less educated labor, foreign-born more educated labor, and native-born more educated labor. Sector data was pulled from IMPLAN and turned into an aggregated SAM (Watson et al., 2012).

This study estimated that when elasticities of substitution are as expected, a reduction in foreign-born less educated labor creates an increase in native-born less educated labor demand. Reductions in Idaho’s GDP, total economic output, and household utility were also expected to occur. This analysis showed negative impacts to the Idaho economy if legislation was passed to limit the supply of foreign-born labor. These results proved to be beneficial as many states in the U.S. were either considering or had already enacted a restriction to foreign-born labor (Watson et al., 2012).

As indicated by this literature review, there are few CGE studies that include land and water as they relate to agricultural production within a region. In addition, there is no current literature that utilizes a CGE model to evaluate these relationships in the state of Texas where saturated thickness of the Ogallala Aquifer is low and continuing to deplete as resources are used mainly for agricultural production. The Palo Duro and Double Mountain Fork Regions of Texas include counties that cover sub-basins of the Ogallala Aquifer and rely on the aquifer for water. This study contributes to the literature by providing information for policy direction in these rural study regions. CGE models have not previously been developed in these two regions, making this study vital to future policy change concerning agriculture.

CHAPTER 3: DATA AND METHODS

Study Region

The study region concentrates on two watershed regions in Texas, the Palo Duro and Double Mountain Fork Regions. These regions heavily rely on the Ogallala Aquifer for agricultural production. Fourteen counties were evaluated. The counties of Dallam, Hansford, Hartley, Hutchinson, Moore, and Sherman were analyzed in the Palo Duro Region, Figure 2 (Uddameri and Ghaseminejad, 2020). In the Double Mountain Fork Region, the counties of Borden, Cochran, Dawson, Garza, Hockley, Lubbock, Lynn, and Terry were chosen for evaluation, Figure 3 (Uddameri and Ghaseminejad, 2020).

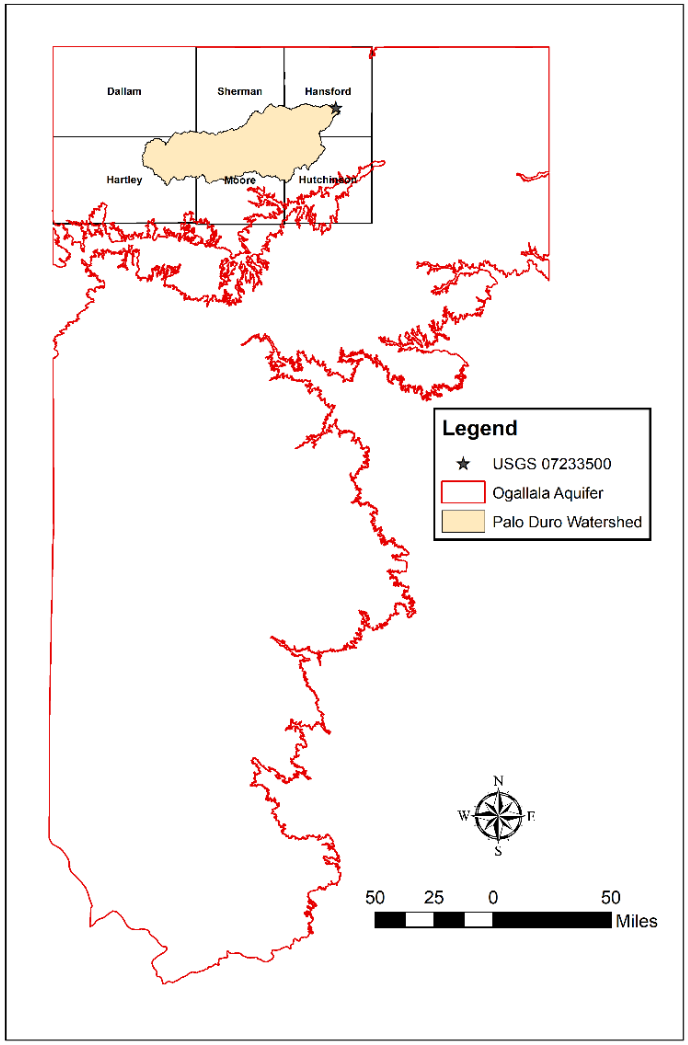

Figure 2. The six counties (overlying the tan shaded area) located within the Palo Duro Region.

Source: Uddameri and Ghaseminejad, 2020.

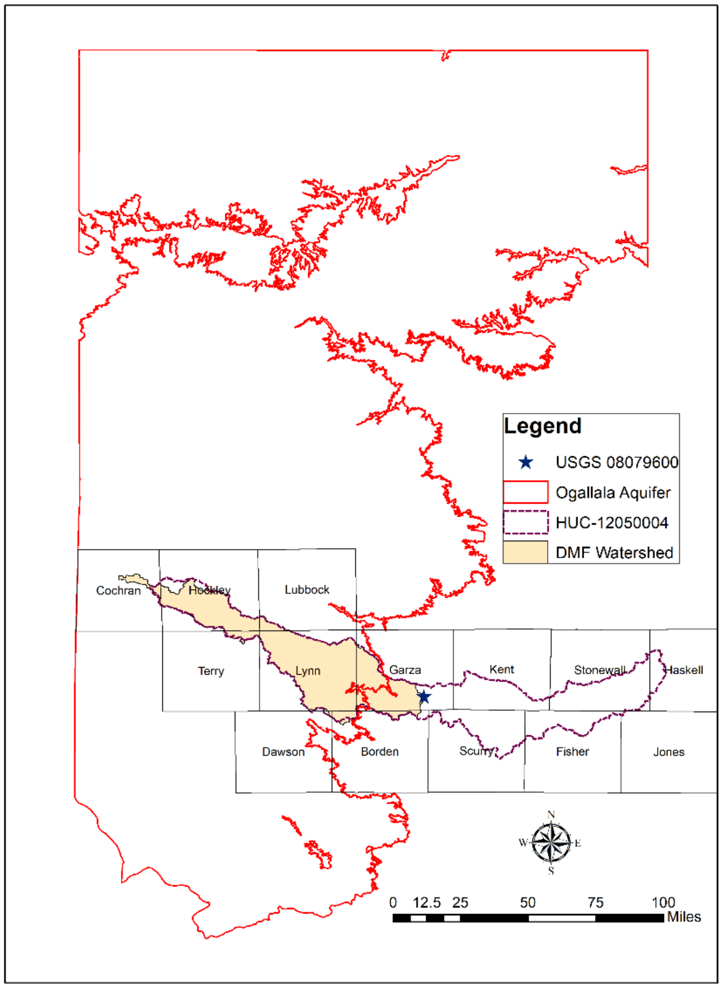

Figure 3. The eight counties (overlying the tan shaded area) located within the Double Mountain Fork Region.

Source: Uddameri and Ghaseminejad, 2020.

Employment, output, and total value added were evaluated for the aggregate IMPLAN sectors for both regions. In the Palo Duro region, the services sector was the biggest for employment (Table 1) and total value added (Table 3) and the manufacturing sector was the biggest for output (Table 2). Services made up 41 percent of the total employment and 22 percent of total value added while manufacturing made up 32.7 percent of total output. Agriculture was the second largest aggregate sector for employment at 14.1 percent and output at 15.9 percent and the fourth largest for total value added at 13.6 percent. In the Double Mountain Fork region, the services sector was the largest for employment (Table 4), output (Table 5), and total value added (Table 6). Services made up 63 percent of total employment, 46.9 percent of total output, and 53.4 percent of total value added. Agriculture was the sixth largest sector for employment at 3.7 percent, the eight largest sector for total value added at 2.5 percent, and the ninth largest sector for output at 2.3 percent. Agriculture made up a larger portion of total employment, output, and value added in the Palo Duro region.

Table 1. Palo Duro Region aggregate IMPLAN sector breakdown for employment

Aggregate Sector	Employment
Services	15,488
Agriculture	5,333
Wholesale and Retail Trade	4,315
Food	3,483
Construction	2,958
Mining	2,505
Manufacturing	2,473
Miscellaneous	1,102
Utilities	150
TOTAL	37,807

Table 2. Palo Duro Region aggregate IMPLAN sector breakdown for output

Aggregate Sector	Output
Manufacturing	$4,274,358,174
Agriculture	$2,071,761,147
Food	$1,839,881,699
Services	$1,697,486,966
Mining	$1,411,686,946
Wholesale and Retail Trade	$733,206,114
Construction	$444,121,697
Miscellaneous	$427,487,141
Utilities	$162,459,574
TOTAL	$13,062,449,459

Table 3. Palo Duro Region aggregate IMPLAN sector breakdown for total value added

Aggregate Sector	Total Value Added
Services	$987,604,334
Manufacturing	$914,757,458
Mining	$726,788,062
Agriculture	$612,018,824
Wholesale and Retail Trade	$420,666,061
Miscellaneous	$276,540,207
Construction	$248,507,545
Food	$237,069,106
Utilities	$64,720,717
TOTAL	$4,488,672,313

Table 4. Double Mountain Fork Region aggregate IMPLAN sector breakdown for employment

Aggregate Sector	Employment
Services	146,552
Wholesale and Retail Trade	29,919
Miscellaneous	15,768
Construction	15,028
Mining	9,229
Agriculture	8,507
Manufacturing	4,765
Food	1,691
Utilities	1,181
TOTAL	232,640

Table 5. Double Mountain Fork Region aggregate IMPLAN sector breakdown for output

Aggregate Sector	Output
Services	$17,186,602,731
Wholesale and Retail Trade	$4,306,210,583
Miscellaneous	$3,741,157,784
Mining	$3,607,117,505
Manufacturing	$2,756,865,475
Construction	$1,953,656,143
Food	$1,124,573,697
Utilities	$1,123,203,948
Agriculture	$833,498,640
TOTAL	$36,632,886,507

Table 6. Double Mountain Fork Region aggregate IMPLAN sector breakdown for total value added

Aggregate Sector	Total Value Added
Services	$9,853,255,876
Wholesale and Retail Trade	$2,392,437,134
Miscellaneous	$2,065,622,740
Mining	$1,511,958,990
Construction	$959,754,640
Manufacturing	$552,482,372
Utilities	4489,921,657
Agriculture	$451,228,745
Food	$165,477,290
TOTAL	$18,442,139,445

General Approach

A CGE model based on the Washington-Idaho CGE model was developed to assess impacts on the economy by combining economic theory with real economic data (Holland et al., 2004). Data were collected for water use, land (including agricultural land use and production), and IMPLAN sectors (IMPLAN Group, LLC, 2013). These data were compiled into a SAM to represent the flow of economic transactions and a "biproportional" matrix balancing technique (RAS procedure) was run in GAMS (GAMS

Development Corporation, 2019) to balance the SAM. The RAS procedure was named after British economist Richard A. Stone who developed the initial RAS framework (Miller and Blair, 2009). The balanced SAM was then input in GAMS to simulate how changes in water, land, and technology for the agricultural sector impacts other sectors of the economy.

The CGE model was run for two regions in the Panhandle of Texas. Results were observed for five different scenarios:

- Baseline with no policy implementation;
- Saturated thickness depletion after 50 years;
- Saturated thickness depletion after 50 years and water reduction policy of 10 percent;
- Saturated thickness depletion after 50 years and land reduction of 10 percent;
- Saturated thickness depletion after 50 years and an average irrigated water share change when switching from a LESA irrigation system to an SDI system.

The results of this model will provide water districts and regional water planners with valuable information as they attempt to create better conservation and water management strategies. Producers could also benefit from knowing how land values will change as water quantities change.

Data and Methods Used

Input-output data for 2019 were obtained from IMPLAN's Regional Industry x Commodity SAM Industry Detail Row Detail file for each region of study, Appendix A. IMPLAN's 26 GAMS files were also pulled for each region to use in the GAMS code. Five subsets of the data, industries, commodities, factors, institutions, and trade, were declared to partition and map the SAM. The IMPLAN data were then split among 30 aggregated accounts. An error code was included in the model code to identify any sectors that were improperly mapped. Adjustments were made to correct any identified mapping errors.

A SAM for each region was then created from the data with columns for expenditures and rows for receipts to represent the flow of economic transactions. A SAM is read from column to row and uses large amounts of data from various resources to give an analysis of the economic structure. Often a SAM will have an imbalance when data is pulled from multiple resources such as cash rents, crop acreage, and land values. To remedy this imbalance, a RAS procedure was added to the GAMS code to balance the SAM. The RAS procedure is a standard procedure for balancing matrices in CGE modeling. After running the RAS procedure, the model was run in GAMS to ensure the SAM was successfully balanced before moving forward.

CGE models have not typically included land and water as factors of production in the past. However, in a previous study, Watson et al. (2012) included land and water as factors of production in a nested CGE analysis concerning foreign-born labor supply. This study was used as an example to add land and water to the model as the main interest of this study was how water depletion and various conservation policies impact rural economy welfare. The capital sector was split into physical capital, land, and water.

Agricultural land use and production data were obtained including crop acreage data from the Farm Service Agency (FSA), Table 7 (Farm Service Agency, 2019). Total agricultural production values were obtained from Texas A&M AgriLife Extension Service increment reports, Table 8 (Texas A&M AgriLife Extension Service, 2018). Cash rental rates were obtained from USDA NASS, Table 9 (National Agricultural Statistics Service, 2019). Total agriculture production value was estimated by taking a three-year average (2016-2018) of each county in the region. These production values were reported in nominal dollars and were not adjusted for inflation.

Table 7. FSA dryland, irrigated, and pasture acreage data (average of 2017-2019)

Region	County	Acres Dryland	Acres Irrigated	Pasture Acres
Palo Duro	Dallam	133,127	233,394	319,733
	Hansford	256,268	182,295	268,658
	Hartley	76,765	261,540	501,276
	Hutchinson	18,598	10,172	215,547
	Moore	138,503	154,853	204,259
	Sherman	165,524	231,897	224,269
	TOTAL	788,784	1,074,151	1,733,742
Double Mountain Fork	Borden	48,668	1,390	168,189
	Cochran	211,318	108,536	47,654
	Dawson	435,652	101,958	53,285
	Garza	60,794	11,283	191,282
	Hockley	334,012	145,326	55,710
	Lubbock	294,851	157,723	14,190
	Lynn	365,051	92,257	34,523
	Terry	315,632	171,843	44,960
	TOTAL	2,065,979	790,315	609,794

Table 8. Total agricultural production values from Texas A&M AgriLife Extension increment reports

Region	County	2016	2017	2018	3 Year Average
Palo Duro	Dallam	$350,442,900	$443,050,800	$436,634,000	$410,042,567
	Hansford	$214,964,100	$423,468,200	$398,552,200	$345,661,500
	Hartley	$417,312,500	$668,356,500	$696,887,930	$594,185,643
	Hutchinson	$19,577,300	$45,053,100	$44,865,900	$36,498,767
	Moore	$365,628,500	$452,779,100	$474,211,990	$430,873,197
	Sherman	$269,221,200	$400,283,600	$391,080,400	$353,528,400
	TOTAL				**$2,170,790,073**
Double Mountain Fork	Borden	$14,635,000	$18,923,300	$18,595,000	$17,384,433
	Cochran	$224,720,200	$172,776,100	$172,681,890	$190,059,397
	Dawson	$155,665,900	$169,235,000	$121,500,000	$148,800,300
	Garza	$155,665,900	$169,235,000	$121,500,000	$148,800,300
	Hockley	$149,482,400	$170,320,000	$127,455,000	$149,085,800
	Lubbock	$229,748,170	$178,073,600	$194,219,600	$200,680,457
	Lynn	$193,727,000	$182,489,200	$185,568,000	$187,261,400
	Terry	$127,173,800	$85,315,000	$65,930,000	$92,806,267
	TOTAL				**$1,134,878,353**

Table 9. Cash rental rates from USDA NASS

	Palo Duro	Double Mountain Fork
Dryland Cash Rental Rate	$ 25.20	$ 31.83
Irrigated Cash Rental Rate	$ 100.83	$ 89.13
Pasture Rental Rate	$ 7.70	$ 5.00
Weighted Non-Irrigation Rental Rate	$ 13.17	$ 25.72

Cash rental rates were used in addition to the total agricultural production value to estimate total irrigated and non-irrigated land values. The non-irrigated rental rate was calculated by taking a weighted average of dryland and pasture rental rates. A production expense proportion for irrigated and non-irrigated land was calculated for both regions. The irrigated proportion was calculated as four percent for both regions. The non-irrigated proportion was calculated as three percent for the Palo Duro region and eight percent for the Double Mountain Fork region, Table 10. These proportions were used to estimate the land and water expenditures that were manually included in the GAMS SAM code.

Table 10. Total irrigation and non-irrigation values based on rental rates

	Palo Duro	**Double Mountain Fork**
Total Ag land value based on rental rates	$ 141,537,427	$ 139,252,786
Ag land value - irrigation	$ 94,161,326	$ 50,111,369
Ag land value - non-irrigation	$ 47,376,101	$ 89,141,417
Production expense proportion for irrigated land	4%	4%
Production expense proportion for non-irrigated land	2%	8%
Ratio of capital to land	2.3	2.3

The model was solved using the Mixed Complementary Problem (MCP) solver in GAMS. The MCP solver is a square model that generates a system of equations with a one-to-one complementary relationship of columns and rows. The production functions are modeled as constant elasticity of substitution (CES) functions. Intermediate input demand is Leontief. Closures were set for all factors based on the counterfactual scenario that was run. Each factor had three closure options. Closure one allowed the factor to be fully employed and mobile while supply was fixed. Closure two allowed the factor to be mobile while supply was variable. Closure three allowed the factor to be activity-specific and fixed. Water was set as closure one. Physical capital was set at closure two. Labor and land were set at closure three.

The baseline scenario evaluated the economy with no policy implementations. The shock for scenario one was calculated using a weighted average of the change in saturated thickness projected over 50 years for Hansford, Hartley, and Moore counties for the Palo Duro region and Hockley and Lynn counties for the Double Mountain Fork region. Saturated thickness was projected to decrease by 71 percent in the Palo Duro region and by 41 percent in the Double Mountain Fork region (Reynolds, 2020).

Scenario two evaluated the impacts of a 10 percent water reduction policy. The counterfactual for this scenario was set to 90 percent of the initial quantity of water demanded by the agricultural sector to evaluate the impact of water reduction in the two regions. Scenario three evaluated the impacts of saturated thickness depletion with a 10 percent reduction in land. The counterfactual for this scenario was set to 90 percent of the initial quantity of land demanded by the agricultural sector.

Scenario four was set to evaluate the impacts of saturated thickness depletion with technology changes. The technology change modeled was a switch in irrigation equipment from a low-energy spray application (LESA) system to a more efficient subsurface drip irrigation (SDI) system. The shock for this scenario was calculated by taking an average irrigation water share change from Texas A&M AgriLife Extension crop budget projections for 2017 (Amosson, et al., 2016), 2018 (Amosson, et al., 2017) , and 2019 (Jones, et al., 2018). The initial water share was seven percent and the new water share was calculated at four percent creating a three percent change in the water share.

Appendix 2 includes additional explanation and a step-by-step breakdown of the CGE modeling procedure.

CHAPTER 4: RESULTS

The CGE model was run in GAMS for all five scenarios for both study regions. Comparisons to the baseline scenario were made for value-added GDP, value of output, land demand, water demand, factor supply, employment, and welfare.

Palo Duro Region

The Palo Duro Region Region is the northern region of this study. This region has more agricultural production than the southern watershed region. The baseline scenario with no policy implementation indicates gross domestic product of $4.49 billion, value of output for agriculture of $2.12 billion, agricultural land demand of $41 million, and agricultural water demand of $83 million. Baseline factor supply is $37.81 billion for labor, $1.68 billion for capital, $565 million for land, and $83 million for water. Agriculture accounts for approximately 5,333 jobs in the Palo Duro Region, Table 11.

Table 11. Comparison of scenarios to the baseline for the Palo Duro Region

	Baseline (Millions of $)	% Change from Baseline			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Gross Domestic Product	$ 4,489	-10.05%	-9.26%	-10.39%	-9.29%
Value of Output					
Agriculture	$ 2,118	-33.95%	-31.31%	-35.06%	-31.32%
Construction	$ 444	-2.11%	-1.94%	-2.19%	-1.95%
Utilities	$ 184	-6.91%	-6.37%	-7.15%	-6.41%
Wholesale and Retail Trade	$ 735	-12.59%	-11.61%	-13.01%	-11.64%
Mining	$ 1,309	2.30%	2.09%	2.39%	2.05%
Food	$ 1,871	-29.14%	-26.82%	-30.13%	-26.83%
Manufacturing	$ 4,354	-2.11%	-1.94%	-2.19%	-1.98%
Services	$ 1,907	-8.14%	-7.51%	-8.41%	-7.54%
Miscellaneous	$ 427	-6.79%	-6.26%	-7.02%	-6.30%
Land Demand					
Agriculture	$ 41	0.00%	0.00%	-10.00%	0.00%
Water Demand					
Agriculture	$ 83	-71.44%	-67.82%	-71.44%	-71.44%
Factor Supply					
Labor	$ 37,807	-12.76%	-11.76%	-13.19%	-11.75%
Capital	$ 1,680	-6.02%	-5.53%	-6.23%	-5.51%
Land	$ 565	0.00%	0.00%	-0.73%	0.00%
Water	$ 83	-71.44%	-67.82%	-71.44%	-71.44%
Employment	# of Jobs				
Agriculture	5,333	-32.68%	-30.11%	-33.78%	-29.87%
Construction	2,958	-1.72%	-1.58%	-1.78%	-1.59%
Utilities	150	-8.13%	-7.50%	-8.40%	-7.53%
Wholesale and Retail Trade	4,315	-12.82%	-11.82%	-13.24%	-11.85%
Mining	2,505	2.69%	2.44%	2.79%	2.40%
Food	3,483	-30.93%	-28.47%	-31.98%	-28.47%
Manufacturing	2,473	-3.66%	-3.36%	-3.79%	-3.39%
Services	15,488	-8.24%	-7.60%	-8.51%	-7.63%
Miscellaneous	1,102	-8.01%	-7.38%	-8.27%	-7.42%
Equivalent Variation (Welfare)		Millions of $			
Household 1		$ 1.56	$ 1.42	$ 1.61	$ 1.41
Household 2		$ (4.16)	$ (3.84)	$ (4.30)	$ (3.89)
Household 3		$ (8.75)	$ (8.06)	$ (9.05)	$ (8.13)
Household 4		$ (11.51)	$ (10.60)	$ (11.90)	$ (10.68)
Household 5		$ (23.11)	$ (21.28)	$ (23.90)	$ (21.45)
Household 6		$ (29.20)	$ (26.88)	$ (30.19)	$ (27.11)
Household 7		$ (30.61)	$ (28.17)	$ (31.65)	$ (28.43)
Household 8		$ (12.97)	$ (11.94)	$ (13.41)	$ (12.05)
Household 9		$ (12.33)	$ (11.35)	$ (12.75)	$ (11.49)

Results indicate that when comparing the baseline scenario and the projected saturated thickness depletion after 50 years scenario (scenario one), an overall decrease in the value-added GDP of 10.05 percent is observed. Water demand decreases by approximately 71.44 percent. Employment and value of output decrease for all aggregated sectors except mining. The largest decrease in employment is in the agriculture sector at 32.68 percent. The largest decrease in value of output is also in the agriculture sector at 33.95 percent. Factor supply decreases by 12.76 percent for labor, 6.02 percent for capital, and 71.44 percent for water. Households two through nine see a decrease in overall welfare while household one sees an increase in overall welfare. Household one increases by $1.56 million. The largest decrease in household welfare is $30.61 million in household 7, Table 11.

Results indicate that when comparing the baseline scenario and the projected saturated thickness depletion after 50 years scenario with the 10 percent irrigated acreage reduction scenario (scenario two), an overall decrease in the value-added GDP of 9.26 percent is observed. Water demand decreases by approximately 67.82 percent. The difference in water demand from scenario one to scenario two is not exactly 10 percent due to the data that was initially used coming from a dynamic economic optimization model where there was an annual reduction of 10 percent applied to changing levels of saturated thickness over the 50-year study period. Employment and value of output decrease for all aggregated sectors except mining. The largest decrease in employment is in the agriculture sector at 30.11 percent. The largest decrease in value of output is also in the agriculture sector at 31.31 percent. Factor supply decreases by 11.76 percent for labor, 5.53 percent for capital, and 67.82 percent for water. Households two through nine see a decrease in overall welfare while household one sees an increase in overall welfare. Household one increases by $1.42 million. The largest decrease in household welfare is $28.17 million in household 7, Table 11.

Results indicate that when comparing the baseline and projected saturated thickness depletion after 50 years scenario in addition to the 10 percent land reduction scenario (scenario three), an overall decrease in the value-added GDP of 10.39 percent is observed. As land demand decreases by 10 percent, the factor supply of land decreases by 0.73 percent. Employment and value of output decrease for all sectors except mining. The highest decrease in employment is in the agriculture sector at 33.78 percent. The largest decrease in value of output is also in the agriculture sector at 35.06 percent. Welfare decreases in households two through nine. Household one increases by $1.61 million. The largest decrease in household welfare is in household seven of $31.65 million, Table 11.

Results indicate that when comparing the baseline scenario and the projected saturated thickness scenario in addition to the technology change scenario (scenario four), an overall decrease in the value-added GDP of 9.29 percent is observed. Factor supply decreases by 11.75 percent for labor, 5.51 percent for capital, and 71.44 percent for water. Employment and value of output increase for all sectors except mining. Employment has the highest decrease in jobs in the agriculture sector of 29.87 percent. Value of output has the highest decrease in the agriculture sector of about 31.32 percent. Households two through nine are overall worse off while household one is overall better off. Household one increases by $1.41 million. The largest decrease in household welfare is observed in household seven of $28.43 million, Table 11.

Overall, the projected saturated thickness depletion scenario with the land reduction scenario (scenario three) has the largest negative impact on the overall economy, while the saturated thickness depletion scenario with the water reduction scenario (scenario two) mitigates some of the negative changes to GDP through policy for the Palo Duro region. Scenario two represents a scenario where there is less water available for current production in order to save water for the future. While scenario two seems to be the best scenario, the negative impacts to production during the 50-year time horizon while water is being saved has not been accounted for.

Double Mountain Fork Region

The Double Mountain Fork Region is the southern region of this study. This region has less agricultural production than the Palo Duro Region. The baseline scenario with no policy implementation indicates gross domestic product of $18.44 billion, value of output for agriculture of $864 million, agricultural land demand of $67 million, and agricultural water demand of $33 million. Baseline factor supply is $232.64 billion for labor, $4.65 billion for capital, $2 billion for land, and $33 million for water. Agriculture accounts for approximately 8.51 billion jobs in the Double Mountain Fork region, Table 12.

Table 12. Comparison of scenarios to the baseline for the Double Mountain Fork Region

	Baseline (Millions of $)	% Change from Baseline			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Gross Domestic Product	$ 18,442	-0.65%	-0.59%	-0.89%	-0.50%
Value of Output					
Agriculture	$ 864	-11.36%	-10.32%	-15.49%	-8.63%
Construction	$ 1,954	-0.19%	-0.17%	-0.26%	-0.14%
Utilities	$ 1,209	-0.33%	-0.30%	-0.45%	-0.25%
Wholesale and Retail Trade	$ 4,313	-0.48%	-0.43%	-0.65%	-0.37%
Mining	$ 3,421	0.02%	0.02%	0.03%	0.01%
Food	$ 1,116	-3.35%	-3.03%	-4.63%	-2.52%
Manufacturing	$ 2,946	-0.25%	-0.23%	-0.34%	-0.19%
Services	$ 18,435	-0.36%	-0.33%	-0.50%	-0.28%
Miscellaneous	$ 3,840	-0.32%	-0.29%	-0.44%	-0.25%
Land Demand					
Agriculture	$ 67	0.00%	0.00%	10.00%	0.00%
Water Demand					
Irrigated Agriculture	$ 33	-40.88%	-37.79%	-40.88%	-40.88%
Factor Supply					
Labor	$ 232,640	-0.79%	-0.72%	-1.08%	-0.60%
Capital	$ 4,646	-0.38%	-0.34%	-0.52%	-0.28%
Land	$ 2,006	0.00%	0.00%	-0.33%	0.00%
Water	$ 33	-40.88%	-37.79%	-40.88%	-40.88%
Employment	# of Jobs				
Agriculture	8,507	-11.61%	-10.55%	-15.84%	-8.62%
Construction	15,028	-0.20%	-0.18%	-0.27%	-0.15%
Utilities	1,181	-0.36%	-0.32%	-0.49%	-0.27%
Wholesale and Retail Trade	29,919	-0.49%	-0.44%	-0.66%	-0.37%
Mining	9,229	0.01%	0.01%	0.02%	0.00%
Food	1,691	-4.22%	-3.82%	-5.83%	-3.18%
Manufacturing	4,765	-0.32%	-0.29%	-0.44%	-0.25%
Services	146,552	-0.36%	-0.32%	-0.49%	-0.27%
Miscellaneous	15,768	-0.41%	-0.38%	-0.56%	-0.32%
Equivalent Variation (Welfare)		Millions of $			
Household 1		$ 0.71	$ 0.65	$ 0.97	$ 0.53
Household 2		$ (0.75)	$ (0.68)	$ (1.03)	$ (0.59)
Household 3		$ (1.63)	$ (1.48)	$ (2.23)	$ (1.26)
Household 4		$ (2.40)	$ (2.18)	$ (3.28)	$ (1.85)
Household 5		$ (5.43)	$ (4.93)	$ (7.43)	$ (4.18)
Household 6		$ (8.90)	$ (8.08)	$ (12.17)	$ (6.84)
Household 7		$ (9.95)	$ (9.04)	$ (13.61)	$ (7.66)
Household 8		$ (4.18)	$ (3.80)	$ (5.72)	$ (3.23)
Household 9		$ (7.20)	$ (6.54)	$ (9.85)	$ (5.61)

Results indicate that when comparing the baseline scenario and the projected saturated thickness after 50 year scenario (scenario one), an overall decrease in the value-added GDP of 0.65 percent is observed. Water demand decreases by approximately 40.88 percent. Employment and value of output decrease for all aggregated sectors except mining. The largest decrease in employment is in the agriculture sector at 11.61 percent. The largest decrease in value of output is also in the agriculture sector at 11.63 percent. Factor supply decreases by 0.79 percent for labor, 0.38 percent for capital, and 40.88 percent for water. Households two through nine see a decrease in overall welfare while household one sees an increase in overall welfare. Household one increases by $0.71 million. The largest decrease in household welfare is $9.95 million in household 7, Table 12.

Results indicate that when comparing the baseline scenario and the projected saturated thickness depletion scenario with the 10 percent irrigated acreage reduction scenario (scenario two), an overall decrease in the value-added GDP of 0.59 percent is observed. Water demand decreases by approximately 37.79 percent. The percent reduction of water demand is not exactly 10 percent based on the data and weighted average of counties. Employment and value of output decrease for all aggregated sectors except mining. The largest decrease in employment is in the agriculture sector at 10.55 percent. The largest decrease in value of output is also in the agriculture sector at 10.32 percent. Factor supply decreases by 0.72 percent for labor, 0.34 percent for capital, and 37.79 percent for water. Households two through nine see a decrease in overall welfare while household one sees an increase in overall welfare. Household one increases by

$0.65 million. The largest decrease in household welfare is $9.04 million in household 7, Table 12.

Results indicate that when comparing the baseline and projected saturated thickness scenario in addition to the 10 percent land reduction scenario (scenario three), an overall decrease in the value-added GDP of 0.89 percent is observed. As land demand decreases by 10 percent, the factor supply of land decreases by 0.33 percent. Employment and value of output decrease for all sectors except mining. The highest decrease in employment is in the agriculture sector at 15.84 percent. The largest decrease in value of output is also in the agriculture sector at 15.49 percent. Welfare decreases in households two through nine. Household one increases by $0.97 million. The largest decrease in household welfare is in household seven of $13.61 million, Table 12.

Results indicate that when comparing the baseline scenario and the projected saturated thickness scenario in addition to the technology change scenario (scenario four), an overall decrease in the value-added GDP of 0.50 percent. Factor supply decreases by 0.60 percent for labor, 0.28 percent for capital, and 40.88 percent for water. Employment and value of output increase for all sectors except mining. Employment has the highest decrease in jobs in the agriculture sector of 8.62 percent. Value of output has the highest decrease in the agriculture sector of about 8.63 percent. Households two through nine are overall worse off while household one is overall better off. Household one increases by $0.53 million. The largest decrease in household welfare is observed in household seven of $7.66 million, Table 12.

Overall, the projected saturated thickness depletion scenario with the land reduction scenario (scenario three) has the largest negative impact on the overall economy, while the saturated thickness depletion scenario with the technology change (scenario four) mitigates some of the negative changes to GDP through policy for the Double Mountain Fork region. Similar to the Palo Duro region, scenario two represents a scenario where there is less water available for current production in order to save water for the future. While scenario four seems to be the best scenario, the negative cost impacts to producers have not been accounted for.

CHAPTER 5: SUMMARY and DISCUSSION

It is important to simulate policy impacts so that policymakers will have a better understanding of how their local economic sectors react to various changes. Data were collected for land including agricultural land use and production and IMPLAN sectors. Data were compiled into a balanced SAM to represent the flow of economic transactions. The purpose of this research, specifically, was to generate a new CGE modeling procedure for the Texas High Plains as well as evaluate policy alternatives for two different regions.

The collected data was run in GAMS, and comparisons were made between the impacts of different policy scenarios within the two regions. The results of the study were employment impacts, price impacts, and other economy-wide implications of various policy scenarios. In both regions, the land reduction scenario in addition to the projected saturated thickness depletion scenario had the biggest impact on the overall economy. In the Palo Duro Region, the projected saturated thickness scenario with the water reduction scenario mitigates some of the negative changes to GDP through policy, while the projected saturated thickness depletion scenario with the technology change scenario mitigates some of the negative changes in the Double Mountain Fork region. The water reduction scenario only accounts for water savings for the future and does not account for negative impacts to producers. The technology change scenario does not account for any costs to producers associated with the change from a LESA system to an SDI system.

Therefore, further research is needed to determine how the observed impacts from these scenario will change when costs to producers are also evaluated.

There were some limitations to this research. The main focus of this study was to develop a CGE model for the study regions adding water and land as factors of production. While this CGE model provides more detailed economic parameters than IMPLAN, the model developed in this study was rather simplistic. There were limitations in how detailed the model could be and what data could be added. Future research is needed to expand upon this model and add more detail for better and more specific results. Specifically, further development of a nesting feature similar to Watson et al. (2012) would enhance the capabilities of this foundational CGE model. Splitting agriculture in the model into irrigated, dryland, and other agriculture is needed to better evaluate impacts observed from the various scenarios run in the model. Ultimately, this model should be combined with other integrated agronomic, hydrologic, and economic optimization models to give policy makers, water planning districts, and producers a more comprehensive overview of the main factors surrounding groundwater so that they can make the best decisions regarding our natural resources and economy in the future.

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APPENDIX A

Table A-1. IMPLAN Regional Industry x Commodity SAM Industry Detail Row Detail raw data

IMPLAN Sector	Aggregate Account	Payments Description
1	AGR	Oilseed farming
2	AGR	Grain farming
3	AGR	Vegetable and melon farming
4	AGR	Fruit farming
5	AGR	Tree nut farming
6	AGR	Greenhouse, nursery, and floriculture production
7	AGR	Tobacco farming
8	AGR	Cotton farming
9	AGR	Sugarcane and sugar beet farming
10	AGR	All other crop farming
11	AGR	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming
12	AGR	Dairy cattle and milk production
13	AGR	Poultry and egg production
14	AGR	Animal production, except cattle and poultry and eggs
15	AGR	Forestry, forest products, and timber tract production
16	AGR	Commercial logging
17	AGR	Commercial fishing
18	AGR	Commercial hunting and trapping
19	AGR	Support activities for agriculture and forestry
20	MIN	Oil and gas extraction
21	MIN	Coal mining
22	MIN	Copper, nickel, lead, and zinc mining
23	MIN	Iron ore mining
24	MIN	Gold ore mining
25	MIN	Silver ore mining
26	MIN	Uranium-radium-vanadium ore mining
27	MIN	Other metal ore mining
28	MIN	Stone mining and quarrying
29	MIN	Sand and gravel mining
30	MIN	Other clay, ceramic, refractory minerals mining
31	MIN	Potash, soda, and borate mineral mining
32	MIN	Phosphate rock mining

33	MIN	Other chemical and fertilizer mineral mining
34	MIN	Other nonmetallic minerals
35	MIN	Drilling oil and gas wells
36	MIN	Support activities for oil and gas operations
37	MIN	Metal mining services
38	MIN	Other nonmetallic minerals services
39	UTIL	Electric power generation - Hydroelectric
40	UTIL	Electric power generation - Fossil fuel
41	UTIL	Electric power generation - Nuclear
42	UTIL	Electric power generation - Solar
43	UTIL	Electric power generation - Wind
44	UTIL	Electric power generation - Geothermal
45	UTIL	Electric power generation - Biomass
46	UTIL	Electric power generation - All other
47	UTIL	Electric power transmission and distribution
48	UTIL	Natural gas distribution
49	UTIL	Water, sewage, and other systems
50	CONST	Construction of new health care structures
51	CONST	Construction of new manufacturing structures
52	CONST	Construction of new power and communication structures
53	CONST	Construction of new educational and vocational structures
54	CONST	Construction of new highways and streets
55	CONST	Construction of new commercial structures, including farm structures
56	CONST	Construction of other new nonresidential structures
57	CONST	Construction of new single-family residential structures
58	CONST	Construction of new multifamily residential structures
59	CONST	Construction of other new residential structures
60	CONST	Maintenance and repair construction of nonresidential structures
61	CONST	Maintenance and repair construction of residential structures
62	CONST	Maintenance and repair construction of highways, streets, bridges, and tunnels
63	MAN	Dog and cat food manufacturing
64	MAN	Other animal food manufacturing
65	FOOD	Flour milling
66	FOOD	Rice milling
67	FOOD	Malt manufacturing
68	FOOD	Wet corn milling
69	FOOD	Soybean and other oilseed processing
70	FOOD	Fats and oils refining and blending
71	FOOD	Breakfast cereal manufacturing
72	FOOD	Beet sugar manufacturing
73	FOOD	Sugar cane mills and refining
74	FOOD	Nonchocolate confectionery manufacturing

75	FOOD	Chocolate and confectionery manufacturing from cacao beans
76	FOOD	Confectionery manufacturing from purchased chocolate
77	FOOD	Frozen fruits, juices, and vegetables manufacturing
78	FOOD	Frozen specialties manufacturing
79	FOOD	Canned fruits and vegetables manufacturing
80	FOOD	Canned specialties
81	FOOD	Dehydrated food products manufacturing
82	FOOD	Cheese manufacturing
83	FOOD	Dry, condensed, and evaporated dairy product manufacturing
84	FOOD	Fluid milk manufacturing
85	FOOD	Creamery butter manufacturing
86	FOOD	Ice cream and frozen dessert manufacturing
87	FOOD	Frozen cakes and other pastries manufacturing
88	FOOD	Poultry processing
89	FOOD	Animal, except poultry, slaughtering
90	FOOD	Meat processed from carcasses
91	FOOD	Rendering and meat byproduct processing
92	FOOD	Seafood product preparation and packaging
93	FOOD	Bread and bakery product, except frozen, manufacturing
94	FOOD	Cookie and cracker manufacturing
95	FOOD	Dry pasta, mixes, and dough manufacturing
96	FOOD	Tortilla manufacturing
97	FOOD	Roasted nuts and peanut butter manufacturing
98	FOOD	Other snack food manufacturing
99	FOOD	Coffee and tea manufacturing
100	FOOD	Flavoring syrup and concentrate manufacturing
101	FOOD	Mayonnaise, dressing, and sauce manufacturing
102	FOOD	Spice and extract manufacturing
103	FOOD	All other food manufacturing
104	FOOD	Bottled and canned soft drinks & water
105	FOOD	Manufactured ice
106	FOOD	Breweries
107	FOOD	Wineries
108	FOOD	Distilleries
109	FOOD	Tobacco product manufacturing
110	MAN	Fiber, yarn, and thread mills
111	MAN	Broadwoven fabric mills
112	MAN	Narrow fabric mills and schiffli machine embroidery
113	MAN	Nonwoven fabric mills
114	MAN	Knit fabric mills
115	MAN	Textile and fabric finishing mills
116	MAN	Fabric coating mills
117	MAN	Carpet and rug mills
118	MAN	Curtain and linen mills
119	MAN	Textile bag and canvas mills

120	MAN	Rope, cordage, twine, tire cord and tire fabric mills
121	MAN	Other textile product mills
122	MAN	Hosiery and sock mills
123	MAN	Other apparel knitting mills
124	MAN	Cut and sew apparel contractors
125	MAN	Men's and boys' cut and sew apparel manufacturing
126	MAN	Women's and girls' cut and sew apparel manufacturing
127	MAN	Other cut and sew apparel manufacturing
128	MAN	Apparel accessories and other apparel manufacturing
129	MAN	Leather and hide tanning and finishing
130	MAN	Footwear manufacturing
131	MAN	Other leather and allied product manufacturing
132	MAN	Sawmills
133	MAN	Wood preservation
134	MAN	Veneer and plywood manufacturing
135	MAN	Engineered wood member and truss manufacturing
136	MAN	Reconstituted wood product manufacturing
137	MAN	Wood windows and door manufacturing
138	MAN	Cut stock, resawing lumber, and planing
139	MAN	Other millwork, including flooring
140	MAN	Wood container and pallet manufacturing
141	MAN	Manufactured home (mobile home) manufacturing
142	MAN	Prefabricated wood building manufacturing
143	MAN	All other miscellaneous wood product manufacturing
144	MAN	Pulp mills
145	MAN	Paper mills
146	MAN	Paperboard mills
147	MAN	Paperboard container manufacturing
148	MAN	Paper bag and coated and treated paper manufacturing
149	MAN	Stationery product manufacturing
150	MAN	Sanitary paper product manufacturing
151	MAN	All other converted paper product manufacturing
152	MAN	Printing
153	MAN	Support activities for printing
154	MAN	Petroleum refineries
155	MAN	Asphalt paving mixture and block manufacturing
156	MAN	Asphalt shingle and coating materials manufacturing
157	MAN	Petroleum lubricating oil and grease manufacturing
158	MAN	All other petroleum and coal products manufacturing
159	MAN	Petrochemical manufacturing
160	MAN	Industrial gas manufacturing
161	MAN	Synthetic dye and pigment manufacturing
162	MAN	Other basic inorganic chemical manufacturing
163	MAN	Other basic organic chemical manufacturing
164	MAN	Plastics material and resin manufacturing

165	MAN	Synthetic rubber manufacturing
166	MAN	Artificial and synthetic fibers and filaments manufacturing
167	MAN	Nitrogenous fertilizer manufacturing
168	MAN	Phosphatic fertilizer manufacturing
169	MAN	Fertilizer mixing
170	MAN	Pesticide and other agricultural chemical manufacturing
171	MAN	Medicinal and botanical manufacturing
172	MAN	Pharmaceutical preparation manufacturing
173	MAN	In-vitro diagnostic substance manufacturing
174	MAN	Biological product (except diagnostic) manufacturing
175	MAN	Paint and coating manufacturing
176	MAN	Adhesive manufacturing
177	MAN	Soap and other detergent manufacturing
178	MAN	Polish and other sanitation good manufacturing
179	MAN	Surface active agent manufacturing
180	MAN	Toilet preparation manufacturing
181	MAN	Printing ink manufacturing
182	MAN	Explosives manufacturing
183	MAN	Custom compounding of purchased resins
184	MAN	Photographic film and chemical manufacturing
185	MAN	Other miscellaneous chemical product manufacturing
186	MAN	Plastics packaging materials and unlaminated film and sheet manufacturing
187	MAN	Unlaminated plastics profile shape manufacturing
188	MAN	Plastics pipe and pipe fitting manufacturing
189	MAN	Laminated plastics plate, sheet (except packaging), and shape manufacturing
190	MAN	Polystyrene foam product manufacturing
191	MAN	Urethane and other foam product (except polystyrene) manufacturing
192	MAN	Plastics bottle manufacturing
193	MAN	Other plastics product manufacturing
194	MAN	Tire manufacturing
195	MAN	Rubber and plastics hoses and belting manufacturing
196	MAN	Other rubber product manufacturing
197	MAN	Pottery, ceramics, and plumbing fixture manufacturing
198	MAN	Brick, tile, and other structural clay product manufacturing
199	MAN	Flat glass manufacturing
200	MAN	Other pressed and blown glass and glassware manufacturing
201	MAN	Glass container manufacturing
202	MAN	Glass product manufacturing made of purchased glass
203	MAN	Cement manufacturing
204	MAN	Ready-mix concrete manufacturing
205	MAN	Concrete block and brick manufacturing
206	MAN	Concrete pipe manufacturing

207	MAN	Other concrete product manufacturing
208	MAN	Lime manufacturing
209	MAN	Gypsum product manufacturing
210	MAN	Abrasive product manufacturing
211	MAN	Cut stone and stone product manufacturing
212	MAN	Ground or treated mineral and earth manufacturing
213	MAN	Mineral wool manufacturing
214	MAN	Miscellaneous nonmetallic mineral products manufacturing
215	MAN	Iron and steel mills and ferroalloy manufacturing
216	MAN	Iron, steel pipe and tube manufacturing from purchased steel
217	MAN	Rolled steel shape manufacturing
218	MAN	Steel wire drawing
219	MAN	Alumina refining and primary aluminum production
220	MAN	Secondary smelting and alloying of aluminum
221	MAN	Aluminum sheet, plate, and foil manufacturing
222	MAN	Other aluminum rolling, drawing and extruding
223	MAN	Nonferrous metal (exc aluminum) smelting and refining
224	MAN	Copper rolling, drawing, extruding and alloying
225	MAN	Nonferrous metal, except copper and aluminum, shaping
226	MAN	Secondary processing of other nonferrous metals
227	MAN	Ferrous metal foundries
228	MAN	Nonferrous metal foundries
229	MAN	Custom roll forming
230	MAN	Crown and closure manufacturing and metal stamping
231	MAN	Iron and steel forging
232	MAN	Nonferrous forging
233	MAN	Cutlery, utensil, pot, and pan manufacturing
234	MAN	Handtool manufacturing
235	MAN	Prefabricated metal buildings and components manufacturing
236	MAN	Fabricated structural metal manufacturing
237	MAN	Plate work manufacturing
238	MAN	Metal window and door manufacturing
239	MAN	Sheet metal work manufacturing
240	MAN	Ornamental and architectural metal work manufacturing
241	MAN	Power boiler and heat exchanger manufacturing
242	MAN	Metal tank (heavy gauge) manufacturing
243	MAN	Metal cans manufacturing
244	MAN	Metal barrels, drums and pails manufacturing
245	MAN	Hardware manufacturing
246	MAN	Spring and wire product manufacturing
247	MAN	Machine shops
248	MAN	Turned product and screw, nut, and bolt manufacturing
249	MAN	Metal heat treating
250	MAN	Metal coating and nonprecious engraving
251	MAN	Electroplating, anodizing, and coloring metal

252	MAN	Valve and fittings, other than plumbing, manufacturing
253	MAN	Plumbing fixture fitting and trim manufacturing
254	MAN	Ball and roller bearing manufacturing
255	MAN	Small arms ammunition manufacturing
256	MAN	Ammunition, except for small arms, manufacturing
257	MAN	Small arms, ordnance, and accessories manufacturing
258	MAN	Fabricated pipe and pipe fitting manufacturing
259	MAN	Other fabricated metal manufacturing
260	MAN	Farm machinery and equipment manufacturing
261	MAN	Lawn and garden equipment manufacturing
262	MAN	Construction machinery manufacturing
263	MAN	Mining machinery and equipment manufacturing
264	MAN	Oil and gas field machinery and equipment manufacturing
265	MAN	Semiconductor machinery manufacturing
266	MAN	Food product machinery manufacturing
267	MAN	Sawmill, woodworking, and paper machinery
268	MAN	Printing machinery and equipment manufacturing
269	MAN	All other industrial machinery manufacturing
270	MAN	Optical instrument and lens manufacturing
271	MAN	Photographic and photocopying equipment manufacturing
272	MAN	Other commercial service industry machinery manufacturing
273	MAN	Air purification and ventilation equipment manufacturing
274	MAN	Heating equipment (except warm air furnaces) manufacturing
275	MAN	Air conditioning, refrigeration, and warm air heating equipment manufacturing
276	MAN	Industrial mold manufacturing
277	MAN	Special tool, die, jig, and fixture manufacturing
278	MAN	Cutting tool and machine tool accessory manufacturing
279	MAN	Machine tool manufacturing
280	MAN	Rolling mill and other metalworking machinery manufacturing
281	MAN	Turbine and turbine generator set units manufacturing
282	MAN	Speed changer, industrial high-speed drive, and gear manufacturing
283	MAN	Mechanical power transmission equipment manufacturing
284	MAN	Other engine equipment manufacturing
285	MAN	Pump and pumping equipment manufacturing
286	MAN	Air and gas compressor manufacturing
287	MAN	Elevator and moving stairway manufacturing
288	MAN	Conveyor and conveying equipment manufacturing
289	MAN	Overhead cranes, hoists, and monorail systems manufacturing
290	MAN	Industrial truck, trailer, and stacker manufacturing
291	MAN	Power-driven handtool manufacturing
292	MAN	Welding and soldering equipment manufacturing
293	MAN	Packaging machinery manufacturing

294	MAN	Industrial process furnace and oven manufacturing
295	MAN	Fluid power cylinder and actuator manufacturing
296	MAN	Fluid power pump and motor manufacturing
297	MAN	Scales, balances, and miscellaneous general purpose machinery manufacturing
298	MAN	Electronic computer manufacturing
299	MAN	Computer storage device manufacturing
300	MAN	Computer terminals and other computer peripheral equipment manufacturing
301	MAN	Telephone apparatus manufacturing
302	MAN	Broadcast and wireless communications equipment manufacturing
303	MAN	Other communications equipment manufacturing
304	MAN	Audio and video equipment manufacturing
305	MAN	Printed circuit assembly (electronic assembly) manufacturing
306	MAN	Bare printed circuit board manufacturing
307	MAN	Semiconductor and related device manufacturing
308	MAN	Capacitor, resistor, coil, transformer, and other inductor manufacturing
309	MAN	Electronic connector manufacturing
310	MAN	Other electronic component manufacturing
311	MAN	Electromedical and electrotherapeutic apparatus manufacturing
312	MAN	Search, detection, and navigation instruments manufacturing
313	MAN	Automatic environmental control manufacturing
314	MAN	Industrial process variable instruments manufacturing
315	MAN	Totalizing fluid meter and counting device manufacturing
316	MAN	Electricity and signal testing instruments manufacturing
317	MAN	Analytical laboratory instrument manufacturing
318	MAN	Irradiation apparatus manufacturing
319	MAN	Watch, clock, and other measuring and controlling device manufacturing
320	MAN	Blank magnetic and optical recording media manufacturing
321	MAN	Software and other prerecorded and record reproducing
322	MAN	Electric lamp bulb and part manufacturing
323	MAN	Lighting fixture manufacturing
324	MAN	Small electrical appliance manufacturing
325	MAN	Household cooking appliance manufacturing
326	MAN	Household refrigerator and home freezer manufacturing
327	MAN	Household laundry equipment manufacturing
328	MAN	Other major household appliance manufacturing
329	MAN	Power, distribution, and specialty transformer manufacturing
330	MAN	Motor and generator manufacturing
331	MAN	Switchgear and switchboard apparatus manufacturing
332	MAN	Relay and industrial control manufacturing

333	MAN	Storage battery manufacturing
334	MAN	Primary battery manufacturing
335	MAN	Fiber optic cable manufacturing
336	MAN	Other communication and energy wire manufacturing
337	MAN	Wiring device manufacturing
338	MAN	Carbon and graphite product manufacturing
339	MAN	All other miscellaneous electrical equipment and component manufacturing
340	MAN	Automobile manufacturing
341	MAN	Light truck and utility vehicle manufacturing
342	MAN	Heavy duty truck manufacturing
343	MAN	Motor vehicle body manufacturing
344	MAN	Truck trailer manufacturing
345	MAN	Motor home manufacturing
346	MAN	Travel trailer and camper manufacturing
347	MAN	Motor vehicle gasoline engine and engine parts manufacturing
348	MAN	Motor vehicle electrical and electronic equipment manufacturing
349	MAN	Motor vehicle transmission and power train parts manufacturing
350	MAN	Motor vehicle seating and interior trim manufacturing
351	MAN	Motor vehicle metal stamping
352	MAN	Other motor vehicle parts manufacturing
353	MAN	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing
354	MAN	Aircraft manufacturing
355	MAN	Aircraft engine and engine parts manufacturing
356	MAN	Other aircraft parts and auxiliary equipment manufacturing
357	MAN	Guided missile and space vehicle manufacturing
358	MAN	Propulsion units and parts for space vehicles and guided missiles manufacturing
359	MAN	Railroad rolling stock manufacturing
360	MAN	Ship building and repairing
361	MAN	Boat building
362	MAN	Motorcycle, bicycle, and parts manufacturing
363	MAN	Military armored vehicle, tank, and tank component manufacturing
364	MAN	All other transportation equipment manufacturing
365	MAN	Wood kitchen cabinet and countertop manufacturing
366	MAN	Upholstered household furniture manufacturing
367	MAN	Nonupholstered wood household furniture manufacturing
368	MAN	Other household nonupholstered furniture manufacturing
369	MAN	Institutional furniture manufacturing
370	MAN	Wood office furniture manufacturing

371	MAN	Custom architectural woodwork and millwork
372	MAN	Office furniture, except wood, manufacturing
373	MAN	Showcase, partition, shelving, and locker manufacturing
374	MAN	Mattress manufacturing
375	MAN	Blind and shade manufacturing
376	MAN	Surgical and medical instrument manufacturing
377	MAN	Surgical appliance and supplies manufacturing
378	MAN	Dental equipment and supplies manufacturing
379	MAN	Ophthalmic goods manufacturing
380	MAN	Dental laboratories
381	MAN	Jewelry and silverware manufacturing
382	MAN	Sporting and athletic goods manufacturing
383	MAN	Doll, toy, and game manufacturing
384	MAN	Office supplies (except paper) manufacturing
385	MAN	Sign manufacturing
386	MAN	Gasket, packing, and sealing device manufacturing
387	MAN	Musical instrument manufacturing
388	MAN	Fasteners, buttons, needles, and pins manufacturing
389	MAN	Broom, brush, and mop manufacturing
390	MAN	Burial casket manufacturing
391	MAN	All other miscellaneous manufacturing
392	TRAD	Wholesale - Motor vehicle and motor vehicle parts and supplies
393	TRAD	Wholesale - Professional and commercial equipment and supplies
394	TRAD	Wholesale - Household appliances and electrical and electronic goods
395	TRAD	Wholesale - Machinery, equipment, and supplies
396	TRAD	Wholesale - Other durable goods merchant wholesalers
397	TRAD	Wholesale - Drugs and druggists’ sundries
398	TRAD	Wholesale - Grocery and related product wholesalers
399	TRAD	Wholesale - Petroleum and petroleum products
400	TRAD	Wholesale - Other nondurable goods merchant wholesalers
401	TRAD	Wholesale - Wholesale electronic markets and agents and brokers
402	TRAD	Retail - Motor vehicle and parts dealers
403	TRAD	Retail - Furniture and home furnishings stores
404	TRAD	Retail - Electronics and appliance stores
405	TRAD	Retail - Building material and garden equipment and supplies stores
406	TRAD	Retail - Food and beverage stores
407	TRAD	Retail - Health and personal care stores
408	TRAD	Retail - Gasoline stores
409	TRAD	Retail - Clothing and clothing accessories stores

410	TRAD	Retail - Sporting goods, hobby, musical instrument and book stores
411	TRAD	Retail - General merchandise stores
412	TRAD	Retail - Miscellaneous store retailers
413	TRAD	Retail - Nonstore retailers
414	SER	Air transportation
415	SER	Rail transportation
416	SER	Water transportation
417	SER	Truck transportation
418	SER	Transit and ground passenger transportation
419	SER	Pipeline transportation
420	SER	Scenic and sightseeing transportation and support activities for transportation
421	SER	Couriers and messengers
422	SER	Warehousing and storage
423	SER	Newspaper publishers
424	SER	Periodical publishers
425	SER	Book publishers
426	SER	Directory, mailing list, and other publishers
427	SER	Greeting card publishing
428	SER	Software publishers
429	SER	Motion picture and video industries
430	SER	Sound recording industries
431	SER	Radio and television broadcasting
432	SER	Cable and other subscription programming
433	SER	Wired telecommunications carriers
434	SER	Wireless telecommunications carriers (except satellite)
435	SER	Satellite, telecommunications resellers, and all other telecommunications
436	SER	Data processing, hosting, and related services
437	SER	News syndicates, libraries, archives and all other information services
438	SER	Internet publishing and broadcasting and web search portals
439	SER	Nondepository credit intermediation and related activities
440	SER	Securities and commodity contracts intermediation and brokerage
441	SER	Monetary authorities and depository credit intermediation
442	SER	Other financial investment activities
443	SER	Direct life insurance carriers
444	SER	Insurance carriers, except direct life
445	SER	Insurance agencies, brokerages, and related activities
446	SER	Funds, trusts, and other financial vehicles
447	MISC	Other real estate
448	MISC	Tenant-occupied housing
449	MISC	Owner-occupied dwellings

450	SER	Automotive equipment rental and leasing
451	SER	General and consumer goods rental except video tapes and discs
452	SER	Video tape and disc rental
453	SER	Commercial and industrial machinery and equipment rental and leasing
454	SER	Lessors of nonfinancial intangible assets
455	SER	Legal services
456	SER	Accounting, tax preparation, bookkeeping, and payroll services
457	SER	Architectural, engineering, and related services
458	SER	Specialized design services
459	SER	Custom computer programming services
460	SER	Computer systems design services
461	SER	Other computer related services, including facilities management
462	SER	Management consulting services
463	SER	Environmental and other technical consulting services
464	SER	Scientific research and development services
465	SER	Advertising, public relations, and related services
466	SER	Photographic services
467	SER	Veterinary services
468	SER	Marketing research and all other miscellaneous professional, scientific, and technical services
469	SER	Management of companies and enterprises
470	SER	Office administrative services
471	SER	Facilities support services
472	SER	Employment services
473	SER	Business support services
474	SER	Travel arrangement and reservation services
475	SER	Investigation and security services
476	SER	Services to buildings
477	SER	Landscape and horticultural services
478	SER	Other support services
479	SER	Waste management and remediation services
480	SER	Elementary and secondary schools
481	SER	Junior colleges, colleges, universities, and professional schools
482	SER	Other educational services
483	SER	Offices of physicians
484	SER	Offices of dentists
485	SER	Offices of other health practitioners
486	SER	Outpatient care centers
487	SER	Medical and diagnostic laboratories
488	SER	Home health care services

489	SER	Other ambulatory health care services
490	SER	Hospitals
491	SER	Nursing and community care facilities
492	SER	Residential mental retardation, mental health, substance abuse and other facilities
493	SER	Individual and family services
494	SER	Child day care services
495	SER	Community food, housing, and other relief services, including rehabilitation services
496	SER	Performing arts companies
497	SER	Commercial Sports Except Racing
498	SER	Racing and Track Operation
499	SER	Independent artists, writers, and performers
500	SER	Promoters of performing arts and sports and agents for public figures
501	SER	Museums, historical sites, zoos, and parks
502	SER	Amusement parks and arcades
503	SER	Gambling industries (except casino hotels)
504	SER	Other amusement and recreation industries
505	SER	Fitness and recreational sports centers
506	SER	Bowling centers
507	SER	Hotels and motels, including casino hotels
508	SER	Other accommodations
509	SER	Full-service restaurants
510	SER	Limited-service restaurants
511	SER	All other food and drinking places
512	SER	Automotive repair and maintenance, except car washes
513	SER	Car washes
514	SER	Electronic and precision equipment repair and maintenance
515	SER	Commercial and industrial machinery and equipment repair and maintenance
516	SER	Personal and household goods repair and maintenance
517	SER	Personal care services
518	SER	Death care services
519	SER	Dry-cleaning and laundry services
520	SER	Other personal services
521	MISC	Religious organizations
522	MISC	Grantmaking, giving, and social advocacy organizations
523	MISC	Business and professional associations
524	MISC	Labor and civic organizations
525	MISC	Private households
526	SER	Postal service
527	UTIL	Federal electric utilities
528	MISC	Other federal government enterprises
529	MISC	State government passenger transit

530	UTIL	State government electric utilities
531	MISC	Other state government enterprises
532	MISC	Local government passenger transit
533	UTIL	Local government electric utilities
534	MISC	Other local government enterprises
535	MISC	* Not an industry (Used and secondhand goods)
536	MISC	* Not an industry (Scrap)
537	MISC	* Not an industry (Rest of world adjustment)
538	MISC	* Not an industry (Noncomparable foreign imports)
539	SER	* Employment and payroll of state govt, education
540	SER	* Employment and payroll of state govt, hospitals and health services
541	SER	* Employment and payroll of state govt, other services
542	SER	* Employment and payroll of local govt, education
543	SER	* Employment and payroll of local govt, hospitals and health services
544	SER	* Employment and payroll of local govt, other services
545	SER	* Employment and payroll of federal govt, military
546	SER	* Employment and payroll of federal govt, non-military
5001	LAB	Employee Compensation
6001	CAP	Proprietor Income
7001	CAP	Other Property Type Income
8001	INDT	Taxes on Production and Imports
10001	HHD1	Households LT15k
10002	HHD2	Households 15-30k
10003	HHD3	Households 30-40k
10004	HHD4	Households 40-50k
10005	HHD5	Households 50-70k
10006	HHD6	Households 70-100k
10007	HHD7	Households 100-150k
10008	HHD8	Households 150-200k
10009	HHD9	Households 200k+
11001	FGOVND	Federal Government NonDefense
11002	FGOVD	Federal Government Defense
11003	FGOVI	Federal Government Investment
12001	SGOVNE	State/Local Govt NonEducation
12002	SGOVE	State/Local Govt Education
12003	SGOVI	State/Local Govt Investment
13001	INV	corporations
14001	INV	Capital
14002	INV	Inventory Additions/Deletions
25001	FT	Foreign Trade
28001	DT	Domestic Trade

APPENDIX B

STEP BY STEP OF CGE MODEL

1. Determined two study regions
    - Double Mountain Fork
    - Palo Duro Regions
2. Pulled "Regional IxC Sam Industry Detail Row Detail" data and 26 GAMS files from IMPLAN for both regions for 2019
3. Aggregated the IMPLAN sectors into 30 accounts
    - AGR, CONST, UTIL, TRAD, MIN, FOOD, MAN, SER, MISC, LAB, CAP, INDT, HHD1, HHD2, HHD3, HHD4, HHD5, HHD6, HHD7, HHD8, HHD9, FGOVND, FGOVD, FGOVI, SGOVNE, SGOVE, SGOVI, INV, FT, DT
4. Calculated Land Data
    - Acres Dryland
        - Averaged county data from FSA Crop Acreage Data 2015-2019 (3-year averages 17-19)
    - Acres Irrigated
        - Averaged county data from FSA Crop Acreage Data 2015-2019 (3-year averages 17-19)
    - Pasture Acres
        - Averaged county data from FSA Crop Acreage Data 2015-2019 (3-year averages 17-19)
    - Dryland Cash Rental Rates
        - Average of county data pulled from USDA NASS for 2019
    - Irrigated Cash Rental Rates
        - Average of county data pulled from USDA NASS for 2019
    - Pasture Rental
        - Average of county data pulled from USDA NASS for 2019
    - Agricultural Value
        - Came from the District 1 (PD) and 2 (DMF) 2018 increment report from TAMU Agrilife extension for crops and livestock (nominal dollars - not adjusted for inflation)
    - Ag Land Value
        - (dryland cash rental rate * acres dry) + (irrigated cash rental rate * acres irrigated) + (pasture rental *pasture acres)

- Ag Water Value
  - (Irrigated cash rental – average dryland cash rental) * acres irrigated
    - Average dryland cash rental = (dryland cash rental * acres dry) / (acres dry + pasture acres) + (pasture rental*pasture acres) / (pasture acres + acres dry)
- Ag Land Value without water
  - Ag land value – ag water value
- Proportion without water
  - Agricultural value / ag land value without water
- Proportion with water
  - Agricultural value / ag water value
- Ratio of K to Land
  - An estimate from Dale Manning's previous work (2.3)

5. Coding in GAMS
   - Run code in the following order:
     - CHECK file
     - Aggregate file
     - Maps file
     - SAM file
     - GAM2XCL file
     - Model file
     - Report file
     - SAM modified file
     - Model modified file
     - Report file
       - Gives you the Report output file

CHECK File

- PROGPATH folder is where MAP and Aggregate files are located
- DATAPATH folder is where GAMS 26 files are located
- DATANAM is the common suffix of the 26 data files from GAMS
  - File Name Example: GAMSPD Files (Text304) 1x1.dat
- If ADJUST is set to NO, activities will be imported and exported
- If ADJUST is set to YES, commodities will be imported and exported
- Set R rows and columns in the SAM
- Declare subsets to partition the SAM
  - Industries = A
    - 1-546
  - Commodities = C
    - 3001-3546

- Factors = F
    - 5001, 6001, 7001, 8001
  - Institutions = I
    - 10001-10009, 11001-11003,12001-12003,13001,14001-14002
  - Trade = T
    - 25001, 28001
- Create the parameter SAM
- Read in 26 GAMS files data
- Read the satellite tables from the 26 GAMS files data
  - Parameters:
    - FEXPORT
    - DEXPORT
    - FIMPORT
    - DIMPORT
    - EMPLOY
- Declare and assign check sums
  - Parameters:
    - SAM_CHK (R)
    - EXPORT_CHK
    - IMPORT_CHK
  - Use ROUND to ignore trivial imbalances
- Retrieve capital flows (balance of payment deficits)
  - Parameter:
    - BOPDEF
- Read in the AGGREG file

Aggregate File

- Reads in the MAP file
- Includes an error code to identify rows that are improperly mapped
- Aggregate into submatrices and assign new labels
  - Parameters:
    - MAKE(K,KK)
    - SEXPRT(K,KK)
    - USE(K,KK)
    - IUSE(K,KK)
    - FD(K,KK)
    - FEXPRT(K,KK)
    - IMAKE(K,KK)
    - FS(K,KK)
    - TRNSFER(K,KK)
    - IEXPRT(K,KK)

        - SIMPRT(K,KK)
        - FIMPRT(K,KK)
        - IIMPRT(K,KK)
        - TRNSHP(K,KK)
        - EXPORT(K,K,K)
        - IMPORT(K,K,K)
        - LABOR(K)
- Adjust for any errors found
- Creates and reads data into SAM file
- Structure aggregated SAM

Table B-1. Structure of the aggregated SAM in GAMS coding

		A	C	F	INST	T (FT)	T (DT)
		1	2	3	4	5	6
A	1		MAKE				
C	2	USE			IUSE	CEXPRT	CEXPRT
F	3	FD				FEXPRT	FEXPRT
INST	4		IMAKE	FS	TRNSFR	IEXPRT	IEXPRT
T (FT)	5		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP
T (DT)	6		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP

- Suppress sectors and goods names for vacuous entries
    - Drop sectors and goods not being used
        - SETs:
            - DROPA (K) Sectors not used;
            - DROPC (K) Goods not used;

MAPS File

- Keeps households unaggregated
- Read by the Aggregate file
- Sets K as 30 aggregated SAM accounts
    - AGR, CONST, UTIL, TRAD, MIN, FOOD, MAN, SER, MISC, LAB, CAP, INDT, HHD1, HHD2, HHD3, HHD4, HHD5, HHD6, HHD7, HHD8, HHD9, FGOVND, FGOVD, FGOVI, SGOVNE, SGOVE, SGOVI, INV, FT, DT
- Maps IMPLAN sectors into the aggregated SAM accounts
- Loop code to add commodities (3001-3546) to the mapping following the industry mapping (1-546)
    - LOOP((A,C)$(ORD(C) EQ ORD(A)), MAP(K,C) = MAP(K,A););

SAM File

- Created from AGGREG file

Table B-2. Unbalanced SAM for the Double Mountain Fork region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	149.47	1.23		2.62	0.55	455.09	26.07	12.35
CONST-C	5.23	0.31	0.61	7.34	33.00	1.15	14.12	33.92
UTIL-C	8.40	5.73	486.95	50.04	47.45	12.10	40.29	108.93
TRAD-C	42.86	245.89	7.01	129.86	120.83	82.42	241.24	344.65
MIN-C	1.78	24.68	38.95	0.08	154.72	1.73	496.24	3.91
FOOD-C	1.12			2.81		197.39	46.26	160.76
MAN-C	94.06	480.03	12.79	146.43	458.67	81.64	978.21	743.89
SER-C	31.09	206.13	79.03	1291.50	1236.65	120.16	324.93	5032.22
MISC-C	48.26	29.90	7.95	283.10	43.29	7.42	37.01	892.72
LAB	191.48	537.99	141.64	1226.39	552.56	66.15	263.19	6680.30
CAP	284.93	407.14	282.39	742.03	539.19	90.88	265.03	2595.48
INDT	-25.19	14.62	65.89	424.02	420.21	8.44	24.26	577.48
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	833.50	1953.66	1123.20	4306.21	3607.12	1124.57	2756.87	17186.60
DIFF	4E-06	3E-06	-1E-03	-6E-05	-2E-05	2E-06	-1E-06	-5E-04

Table B-2 Cont. Unbalanced SAM for the Double Mountain Fork region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		823.05						0.06
CONST-A			1953.66					
UTIL-A				1122.38		0.10		
TRAD-A					4306.21			
MIN-A						3403.72		203.40
FOOD-A							1110.94	13.63
MAN-A						3.87	3.86	2727.50
SER-A		0.22			0.01	0.09		
MISC-A				83.78	5.97			
AGR-C	0.46							
CONST-C	190.19							
UTIL-C	82.31							
TRAD-C	42.41							
MIN-C	3.46							
FOOD-C	5.56							
MAN-C	81.17							
SER-C	935.61							
MISC-C	334.36							
LAB	348.99							
CAP	1478.52							
INDT	238.12							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.54		0.03			0.01	
FGOVD								
FGOVI								
SGOVNE		11.22		2.61				
SGOVE								
SGOVI								
INV		28.57			0.40	13.24	1.05	1.19
FT		71.31		1.16		269.20	121.58	1888.19
DT		434.92	47.46	140.97	492.76	65.44	1077.00	4320.75
TOTAL	3741.16	1369.83	2001.12	1350.93	4805.36	3755.66	2314.45	9154.72
DIFF	-2E-05	-6E-12	3E-11	-4E-11	6E-11	4E-12	-7E-11	-3E-11

Table B-2 Cont. Unbalanced SAM for the Double Mountain Fork region

	SER-C	MISC-C	LAB	CAP	INDT	HHD1	HHD2	HHD3
AGR-A	10.38							
CONST-A								
UTIL-A		0.72						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	20.35	1.28						
SER-A	17184.81	1.47						
MISC-A	57.31	3594.09						
AGR-C						5.83	9.41	7.31
CONST-C								
UTIL-C						18.75	29.53	21.36
TRAD-C						151.91	244.93	192.90
MIN-C						0.01	0.02	0.01
FOOD-C						61.28	88.31	70.00
MAN-C						83.38	144.20	114.68
SER-C						413.95	672.31	587.77
MISC-C						172.13	283.52	204.53
LAB								
CAP								
INDT								
HHD1		6.60	50.76	11.06		0.02	0.07	0.07
HHD2		10.02	264.97	50.36		0.06	0.27	0.28
HHD3		10.80	367.54	65.31		0.07	0.28	0.29
HHD4		11.15	478.12	91.84		0.09	0.37	0.39
HHD5		20.96	1118.82	189.30		0.13	0.54	0.57
HHD6		28.13	1750.15	306.11		0.23	0.95	1.01
HHD7		34.10	2101.11	416.74		0.32	1.35	1.43
HHD8		18.48	999.49	236.16		0.22	0.90	0.95
HHD9		32.98	1683.92	788.65		0.58	2.41	2.55
FGOVND		2.21	1063.73	71.62	220.68	-8.60	-29.65	-8.17
FGOVD								
FGOVI		0.54						
SGOVNE	1161.19	29.42	10.58	34.07	1527.17	1.42	8.04	2.62
SGOVE								
SGOVI		33.29						
INV	1.04	3.30		4286.43				
FT	287.07	339.08		17.25		61.63	98.88	70.89
DT	5265.39	893.04	119.52	120.69		-61.63	-98.88	-70.89
TOTAL	23987.55	5071.66	10008.71	6685.58	1747.86	901.77	1457.75	1200.55
DIFF	-3E-10	-1E-11	2E-11	-1E-11	1E-11	-8E-12	9E-12	1E-12

Table B-2 Cont. Unbalanced SAM for the Double Mountain Fork region

	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND	FGOVD
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	6.38	11.14	14.35	14.84	5.41	7.28		0.00
CONST-C							0.10	1.26
UTIL-C	19.82	31.51	35.55	31.52	11.51	13.81	0.06	0.36
TRAD-C	183.44	318.75	384.32	406.52	159.27	213.87	0.24	2.50
MIN-C	0.01	0.02	0.02	0.02	0.01	0.01	0.08	
FOOD-C	63.45	102.95	120.70	121.22	40.82	52.74	0.00	0.60
MAN-C	103.02	183.16	217.21	232.97	96.78	117.00	0.79	10.74
SER-C	589.10	994.50	1285.15	1289.92	532.05	989.58	119.62	65.62
MISC-C	213.78	364.63	471.06	468.76	213.21	316.22	0.81	2.72
LAB								
CAP								
INDT								
HHD1	0.10	0.16	0.29	0.47	0.39	1.16	174.73	
HHD2	0.38	0.63	1.14	1.82	1.53	4.50	505.30	
HHD3	0.40	0.65	1.17	1.88	1.58	4.65	341.14	
HHD4	0.52	0.86	1.55	2.48	2.09	6.15	305.72	
HHD5	0.77	1.26	2.28	3.64	3.06	9.03	389.71	
HHD6	1.36	2.23	4.03	6.44	5.41	15.96	375.70	
HHD7	1.92	3.15	5.69	9.09	7.65	22.54	308.82	
HHD8	1.28	2.10	3.78	6.05	5.09	14.99	104.70	
HHD9	3.42	5.63	10.16	16.24	13.66	40.26	209.20	
FGOVND	19.97	109.79	220.49	356.06	226.16	662.58		
FGOVD							83.79	
FGOVI							92.14	
SGOVNE	2.67	37.17	13.29	9.01	8.82	26.22	507.23	
SGOVE								
SGOVI								
INV				203.59	219.10	707.52		0.00
FT	89.38	148.86	214.66	183.60	69.79	163.59	0.60	3.22
DT	-89.38	-148.86	-214.66	-183.60	-69.79	-163.59	-0.60	-3.22
TOTAL	1211.77	2170.31	2792.22	3182.54	1553.58	3226.08	3519.88	83.79
DIFF	1E-11	3E-11	-1E-11	7E-11	2E-11	2E-11	-6E-11	-9E-13

Table B-2 Cont. Unbalanced SAM for the Double Mountain Fork region

	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A								833.50
CONST-A								1953.66
UTIL-A								1123.20
TRAD-A								4306.21
MIN-A								3607.12
FOOD-A								1124.57
MAN-A								2756.87
SER-A								17186.60
MISC-A								3741.16
AGR-C		11.51	0.53		0.29	294.45	333.26	1369.83
CONST-C	15.85	66.67	19.69	397.73	1196.87	0.15	16.93	2001.12
UTIL-C		31.80	14.03			4.20	244.92	1350.93
TRAD-C	0.94	100.50	22.49	6.63	17.10	343.93	797.94	4805.36
MIN-C		2.30	0.33		233.98	375.89	2417.39	3755.66
FOOD-C		127.46	29.53		2.31	82.95	936.24	2314.45
MAN-C	3.10	310.38	102.16	10.12	2139.05	286.67	1922.41	9154.72
SER-C	72.79	1698.79	1537.54	154.73	348.40	534.29	2844.15	23987.55
MISC-C		74.97	9.74		228.20	183.63	179.75	5071.66
LAB								10008.71
CAP								6685.58
INDT								1747.86
HHD1		40.65			615.23			901.77
HHD2		116.23			500.25			1457.75
HHD3		79.27			325.52			1200.55
HHD4		71.05			239.39			1211.77
HHD5		91.09			339.16			2170.31
HHD6		91.75			202.76			2792.22
HHD7		80.55			188.10			3182.54
HHD8		33.19			126.22			1553.58
HHD9		75.08			341.34			3226.08
FGOVND					612.42			3519.88
FGOVD								83.79
FGOVI					0.00			92.68
SGOVNE					1982.44			5375.20
SGOVE		1736.05						1736.05
SGOVI		535.92			0.00			569.21
INV			0.00		335.24	2314.66	1858.96	9974.28
FT	2.44	82.99	66.00	3.73	165.75	0.00		4420.84
DT	-2.44	-82.99	-66.00	-3.73	-165.75			11551.94
TOTAL	92.68	5375.20	1736.05	569.21	9974.28	4420.84	11551.94	163906.74
DIFF	4E-14	3E-11	7E-12	5E-12	2E-03	5E-11	4E-11	

Table B-3. Unbalanced SAM for the Palo Duro region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	430.07	0.24		0.40	0.23	1019.97	173.40	1.14
CONST-C	4.08	0.06	0.22	1.28	8.26	0.93	38.55	6.03
UTIL-C	18.91	1.13	58.89	7.97	19.68	10.29	89.40	11.46
TRAD-C	226.67	48.49	1.88	21.97	36.01	106.62	236.33	39.91
MIN-C	7.60	4.86	10.22	0.01	62.27	1.14	1553.49	0.51
FOOD-C	16.53			0.68		180.72	322.80	13.59
MAN-C	450.57	94.42	2.82	24.96	149.12	39.63	519.43	86.76
SER-C	123.35	40.53	21.69	213.63	394.03	235.08	396.49	472.61
MISC-C	181.96	5.88	2.02	41.63	15.30	8.43	29.71	77.86
LAB	167.22	148.90	17.29	170.60	261.74	175.73	263.18	652.15
CAP	599.60	96.74	34.19	113.02	315.18	52.71	620.81	280.08
INDT	-154.80	2.87	13.24	137.04	149.87	8.64	30.77	55.38
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	2071.76	444.12	162.46	733.21	1411.69	1839.88	4274.36	1697.49
DIFF	1E-05	6E-07	-1E-04	-1E-05	-9E-06	-1E-05	-1E-05	-2E-05

Table B-3 Cont. Unbalanced SAM for the Palo Duro region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		2060.65						0.02
CONST-A			444.12					
UTIL-A				162.03		0.03		
TRAD-A					733.21			
MIN-A						1290.53		121.16
FOOD-A							1839.83	0.05
MAN-A						11.66	30.59	4229.57
SER-A		0.05			0.00	0.01		
MISC-A				21.97	1.57			
AGR-C	0.03							
CONST-C	24.67							
UTIL-C	4.65							
TRAD-C	5.50							
MIN-C	0.83							
FOOD-C	0.36							
MAN-C	9.93							
SER-C	85.39							
MISC-C	19.58							
LAB	29.38							
CAP	216.13							
INDT	31.03							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.13		0.00			0.00	
FGOVD								
FGOVI								
SGOVNE		1.64		0.38				
SGOVE								
SGOVI								
INV		55.12			0.12	7.20	0.50	3.02
FT		59.35		0.17		361.90	65.52	381.24
DT		565.09	30.50	95.91	458.94	597.89	407.80	1257.56
TOTAL	427.49	2742.02	474.62	280.45	1193.84	2269.22	2344.25	5992.62
DIFF	-2E-06	4E-11	-8E-07	-4E-12	5E-12	-2E-11	2E-12	9E-13

Table B-3 Cont. Unbalanced SAM for the Palo Duro region

	SER-C	MISC-C	LAB	CAP	INDT	HHD1	HHD2	HHD3
AGR-A	11.09							
CONST-A								
UTIL-A		0.40						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	2.34	0.21						
SER-A	1697.22	0.19						
MISC-A	14.71	389.24						
AGR-C						0.68	1.39	1.34
CONST-C								
UTIL-C						2.19	4.35	3.92
TRAD-C						17.79	36.06	35.42
MIN-C						0.00	0.00	0.00
FOOD-C						7.17	13.00	12.85
MAN-C						9.76	21.23	21.05
SER-C						48.46	98.98	107.92
MISC-C						20.15	41.74	37.55
LAB								
CAP								
INDT								
HHD1		0.77	7.13	1.78		0.00	0.01	0.01
HHD2		1.48	47.36	18.89		0.01	0.04	0.05
HHD3		1.98	83.39	26.81		0.01	0.05	0.06
HHD4		2.03	105.89	34.50		0.02	0.07	0.07
HHD5		3.74	243.25	82.28		0.02	0.10	0.10
HHD6		4.69	353.86	121.35		0.04	0.16	0.17
HHD7		5.58	408.12	160.87		0.05	0.22	0.23
HHD8		3.12	201.08	81.26		0.04	0.15	0.16
HHD9		2.98	182.03	162.53		0.05	0.22	0.23
FGOVND		0.28	210.01	30.44	30.27	-1.41	-6.73	-2.21
FGOVD								
FGOVI		0.07						
SGOVNE	181.37	4.29	1.99	12.78	243.76	0.28	3.60	1.02
SGOVE								
SGOVI		5.61						
INV	0.01	0.75		1375.86				
FT	34.38	77.87		5.54		0.51	1.08	1.12
DT	1981.77	410.28	42.08	213.59		-0.51	-1.08	-1.12
TOTAL	3922.89	915.55	1886.18	2328.46	274.03	105.34	214.63	219.94
DIFF	9E-13	-7E-12	2E-12	3E-11	-3E-12	1E-12	7E-13	5E-12

Table B-3 Cont. Unbalanced SAM for the Palo Duro region

	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND	FGOVD
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	1.16	1.99	2.39	2.43	0.91	0.66		0.00
CONST-C							0.01	0.19
UTIL-C	3.60	5.62	5.92	5.15	1.95	1.25	0.01	0.05
TRAD-C	33.33	56.81	64.02	66.49	26.91	19.36	0.03	0.37
MIN-C	0.00	0.00	0.00	0.00	0.00	0.00	0.01	
FOOD-C	11.53	18.35	20.10	19.83	6.90	4.77	0.00	0.09
MAN-C	18.72	32.65	36.18	38.10	16.35	10.59	0.09	1.59
SER-C	107.04	177.26	214.07	210.97	89.88	89.56	14.17	9.69
MISC-C	38.84	64.99	78.47	76.67	36.02	28.62	0.10	0.40
LAB								
CAP								
INDT								
HHD1	0.01	0.02	0.03	0.05	0.05	0.13	20.83	
HHD2	0.06	0.10	0.18	0.29	0.25	0.73	70.23	
HHD3	0.07	0.12	0.22	0.35	0.30	0.87	58.95	
HHD4	0.10	0.16	0.29	0.46	0.39	1.14	51.91	
HHD5	0.14	0.23	0.41	0.66	0.56	1.64	64.71	
HHD6	0.23	0.37	0.68	1.08	0.91	2.68	59.76	
HHD7	0.32	0.52	0.94	1.50	1.26	3.71	47.76	
HHD8	0.21	0.35	0.63	1.01	0.85	2.51	17.80	
HHD9	0.31	0.51	0.91	1.46	1.22	3.61	18.18	
FGOVND	5.23	28.30	52.69	82.72	53.33	85.63		
FGOVD							12.38	
FGOVI							11.66	
SGOVNE	1.06	23.00	7.10	4.40	6.13	8.69	85.58	
SGOVE								
SGOVI								
INV	0.36	19.98	101.27	163.57	92.44	146.03	106.13	
FT	1.09	1.83	2.15	2.06	0.82	0.63	0.01	0.10
DT	-1.09	-1.83	-2.15	-2.06	-0.82	-0.63	-0.01	-0.10
TOTAL	222.31	431.32	586.50	677.21	336.58	412.17	640.29	12.38
DIFF	4E-12	2E-12	-4E-12	-5E-13	-5E-12	5E-12	-3E-12	7E-14

Table B-3 Cont. Unbalanced SAM for the Palo Duro region

	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A								2071.76
CONST-A								444.12
UTIL-A								162.46
TRAD-A								733.21
MIN-A								1411.69
FOOD-A								1839.88
MAN-A								4274.36
SER-A								1697.49
MISC-A								427.49
AGR-C		1.75	0.08		1.09	137.40	963.28	2742.02
CONST-C	2.02	9.02	2.92	89.81	275.57	0.03	10.96	474.62
UTIL-C		3.92	2.08			0.66	17.41	280.45
TRAD-C	0.12	11.59	3.34	1.12	2.65	54.50	40.56	1193.84
MIN-C		0.32	0.05		53.98	204.79	369.12	2269.22
FOOD-C		14.47	4.38		0.82	168.55	1506.75	2344.25
MAN-C	0.39	38.46	15.16	1.70	492.07	466.98	3393.89	5992.62
SER-C	9.20	197.47	203.03	26.06	83.42	72.85	180.06	3922.89
MISC-C		10.73	1.45		52.07	27.50	17.88	915.55
LAB								1886.18
CAP								2328.46
INDT								274.03
HHD1		5.87			68.64			105.34
HHD2		21.45			53.50			214.63
HHD3		19.86			26.89			219.94
HHD4		15.91			9.40			222.31
HHD5		19.93			13.56			431.32
HHD6		18.33			22.20			586.50
HHD7		15.20			30.94			677.21
HHD8		6.33			21.09			336.58
HHD9		7.33			30.60			412.17
FGOVND					71.60			640.29
FGOVD					0.00			12.38
FGOVI								11.73
SGOVNE					176.47			763.52
SGOVE		232.48						232.48
SGOVI		113.09						118.70
INV	0.00		0.00	0.00	333.88			2406.24
FT	0.05	2.68	1.17	0.11	131.89	0.00		1133.26
DT	-0.05	-2.68	-1.17	-0.11	453.90			6499.89
TOTAL	11.73	763.52	232.48	118.70	2406.24	1133.26	6499.89	
DIFF	-2E-15	1E-11	-5E-13	1E-12	2E-04	2E-11	-4E-12	

GAMS2XCL File

- Reads in the SAM.gms file
- Converts the SAM from .gms format to .gdx format to Excel format

MODEL File

- Set global variable LBR
    - LBR No
        - Employment data from IMPLAN will not be used
        - QFO set to numbers in SAM
    - LBR YES
        - Employment data from IMPLAN will be used
        - QFO set to employment data extracted from IMPLAN
        - QF represents the actual number of jobs in this case
- Read in the SAM.gms input file and display SAM
- Add in RAS procedure code
    - Create a subset of set K as set LL(K) to include all activity, commodity, factor, institution, and trading region sectors as well as a total
    - Create a subset of set LL as set MM(LL) to include all activity, commodity, factor, institution, and trading region sectors (this set does not include a total)
    - Set aliases and parameters
        - Parameters:
            - preras (LL,LLL)
            - conflow(MM,hhh) the sam without the totals
            - c0(MM) the totals of each row
            - con(MM) the totals of each row
    - Set variables and equations
        - Parameters:
            - a0(rrr,MMM) Initial coefficients matrix to RAS
            - a1(rrr,MMM) Final coefficients matrix after RAS
            - rasmat0(rrr,MMM) Initial flows matrix to RAS
            - ct(MMM) RAS column control totals
            - rt(rrr) RAS row control totals
            - ratio Adjustment parameter on control totals
            - checkcol Check sum of column control totals
            - checkrow Check sum of row control totals
            - sumccc Original column sums of RAS matrix
            - sumrrr Original row sums of RAS matrix

- Variables
    - DEV Deviations
    - RASMAT(rrr,MMM) RASed matrix
    - R1(rrr) Rho of RAS matrix
    - S1(MMM) Sigma of RAS matrix
    - LOSS Objective (loss) function value
- Equations
    - BIPROP(rrr,MMM) Bi-proportionality for RAS matrix
    - DEVSQ Definition of squared deviations
    - OBJ Objective function
    - EQUAL(MM) Equality constraint for rows=cols

- Set model and solve
    - MODEL CONSUMERAS /
      BIPROP
      OBJ
      EQUAL/;
- Read preras and rased SAM into Excel
    - $libinclude xldump preras PD_newsam_rased.xlsx PD_SAM_preras!a1
    - $libinclude xldump rasmat PD_newsam_rased.xlsx PD_SAM_rased!a1
- Add total back into rased SAM

Table B-4. Balanced SAM for the Double Mountain Fork region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	149.47	1.23		2.62	0.55	455.09	26.07	12.35
CONST-C	5.23	0.31	0.61	7.34	33.00	1.15	14.12	33.92
UTIL-C	8.40	5.73	486.95	50.04	47.45	12.10	40.29	108.93
TRAD-C	42.86	245.89	7.01	129.86	120.83	82.42	241.24	344.65
MIN-C	1.78	24.68	38.95	0.08	154.72	1.73	496.24	3.91
FOOD-C	1.12			2.81		197.39	46.26	160.76
MAN-C	94.06	480.03	12.79	146.43	458.67	81.64	978.21	743.89
SER-C	31.09	206.13	79.03	1291.50	1236.65	120.16	324.93	5032.22
MISC-C	48.26	29.90	7.95	283.10	43.29	7.42	37.01	892.72
LAB	191.48	537.99	141.64	1226.39	552.56	66.15	263.19	6680.30
CAP	284.93	407.14	282.39	742.03	539.19	90.88	265.03	2595.48
INDT	-25.19	14.62	65.89	424.02	420.21	8.44	24.26	577.48
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	833.50	1953.66	1123.20	4306.21	3607.12	1124.57	2756.87	17186.60
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Cont. Balanced SAM for the Double Mountain Fork region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		823.05						0.06
CONST-A			1953.66					
UTIL-A				1122.38		0.10		
TRAD-A					4306.21			
MIN-A						3403.72		203.40
FOOD-A							1110.94	13.63
MAN-A						3.87	3.86	2727.50
SER-A		0.22			0.01	0.09		
MISC-A				83.78	5.97			
AGR-C	0.46							
CONST-C	190.19							
UTIL-C	82.31							
TRAD-C	42.41							
MIN-C	3.46							
FOOD-C	5.56							
MAN-C	81.17							
SER-C	935.61							
MISC-C	334.36							
LAB	348.99							
CAP	1478.52							
INDT	238.12							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.54		0.03			0.01	
FGOVD								
FGOVI								
SGOVNE		11.22		2.61				
SGOVE								
SGOVI								
INV		28.57			0.40	13.24	1.05	1.19
FT		71.31		1.16		269.20	121.58	1888.19
DT		434.92	47.46	140.97	492.76	65.44	1077.00	4320.75
TOTAL	3741.16	1369.83	2001.12	1350.93	4805.36	3755.66	2314.45	9154.72
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Cont. Balanced SAM for the Double Mountain Fork region

	SER-C	MISC-C	LAB	CAP	INDT	HHD1	HHD2	HHD3
AGR-A	10.38							
CONST-A								
UTIL-A		0.72						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	20.35	1.28						
SER-A	17184.81	1.47						
MISC-A	57.31	3594.09						
AGR-C						5.83	9.41	7.31
CONST-C								
UTIL-C						18.75	29.53	21.36
TRAD-C						151.91	244.93	192.90
MIN-C						0.01	0.02	0.01
FOOD-C						61.28	88.31	70.00
MAN-C						83.38	144.20	114.68
SER-C						413.95	672.31	587.77
MISC-C						172.13	283.52	204.53
LAB								
CAP								
INDT								
HHD1		6.60	50.76	11.06		0.02	0.07	0.07
HHD2		10.02	264.97	50.36		0.06	0.27	0.28
HHD3		10.80	367.54	65.31		0.07	0.28	0.29
HHD4		11.15	478.12	91.84		0.09	0.37	0.39
HHD5		20.96	1118.82	189.30		0.13	0.54	0.57
HHD6		28.13	1750.15	306.11		0.23	0.95	1.01
HHD7		34.10	2101.11	416.74		0.32	1.35	1.43
HHD8		18.48	999.49	236.16		0.22	0.90	0.95
HHD9		32.98	1683.92	788.65		0.58	2.41	2.55
FGOVND		2.21	1063.73	71.62	220.68	-8.60	-29.65	-8.17
FGOVD								
FGOVI		0.54						
SGOVNE	1161.19	29.42	10.58	34.07	1527.17	1.42	8.04	2.62
SGOVE								
SGOVI		33.29						
INV	1.04	3.30		4286.43				
FT	287.07	339.08		17.25		61.63	98.88	70.89
DT	5265.39	893.04	119.52	120.69		-61.63	-98.88	-70.89
TOTAL	23987.55	5071.66	10008.71	6685.58	1747.86	901.77	1457.75	1200.55
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Cont. Balanced SAM for the Double Mountain Fork region

	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND	FGOVD
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	6.38	11.14	14.35	14.84	5.41	7.28		0.00
CONST-C							0.10	1.26
UTIL-C	19.82	31.51	35.55	31.52	11.51	13.81	0.06	0.36
TRAD-C	183.44	318.75	384.32	406.52	159.27	213.87	0.24	2.50
MIN-C	0.01	0.02	0.02	0.02	0.01	0.01	0.08	
FOOD-C	63.45	102.95	120.70	121.22	40.82	52.74	0.00	0.60
MAN-C	103.02	183.16	217.21	232.97	96.78	117.00	0.79	10.74
SER-C	589.10	994.50	1285.15	1289.92	532.05	989.58	119.62	65.62
MISC-C	213.78	364.63	471.06	468.76	213.21	316.22	0.81	2.72
LAB								
CAP								
INDT								
HHD1	0.10	0.16	0.29	0.47	0.39	1.16	174.73	
HHD2	0.38	0.63	1.14	1.82	1.53	4.50	505.30	
HHD3	0.40	0.65	1.17	1.88	1.58	4.65	341.14	
HHD4	0.52	0.86	1.55	2.48	2.09	6.15	305.72	
HHD5	0.77	1.26	2.28	3.64	3.06	9.03	389.71	
HHD6	1.36	2.23	4.03	6.44	5.41	15.96	375.70	
HHD7	1.92	3.15	5.69	9.09	7.65	22.54	308.82	
HHD8	1.28	2.10	3.78	6.05	5.09	14.99	104.70	
HHD9	3.42	5.63	10.16	16.24	13.66	40.26	209.20	
FGOVND	19.97	109.79	220.49	356.06	226.16	662.58		
FGOVD							83.79	
FGOVI							92.14	
SGOVNE	2.67	37.17	13.29	9.01	8.82	26.22	507.23	
SGOVE								
SGOVI								
INV				203.59	219.10	707.52		0.00
FT	89.38	148.86	214.66	183.60	69.79	163.59	0.60	3.22
DT	-89.38	-148.86	-214.66	-183.60	-69.79	-163.59	-0.60	-3.22
TOTAL	1211.77	2170.31	2792.22	3182.54	1553.58	3226.08	3519.88	83.79
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-4 Cont. Balanced SAM for the Double Mountain Fork region

	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A								833.50
CONST-A								1953.66
UTIL-A								1123.20
TRAD-A								4306.21
MIN-A								3607.12
FOOD-A								1124.57
MAN-A								2756.87
SER-A								17186.60
MISC-A								3741.16
AGR-C		11.51	0.53		0.29	294.45	333.26	1369.83
CONST-C	15.85	66.67	19.69	397.73	1196.87	0.15	16.93	2001.12
UTIL-C		31.80	14.03			4.20	244.92	1350.93
TRAD-C	0.94	100.50	22.49	6.63	17.10	343.93	797.94	4805.36
MIN-C		2.30	0.33		233.98	375.89	2417.39	3755.66
FOOD-C		127.46	29.53		2.31	82.95	936.24	2314.45
MAN-C	3.10	310.38	102.16	10.12	2139.05	286.67	1922.41	9154.72
SER-C	72.79	1698.79	1537.54	154.73	348.40	534.29	2844.15	23987.55
MISC-C		74.97	9.74		228.20	183.63	179.75	5071.66
LAB								10008.71
CAP								6685.58
INDT								1747.86
HHD1		40.65			615.23			901.77
HHD2		116.23			500.25			1457.75
HHD3		79.27			325.52			1200.55
HHD4		71.05			239.39			1211.77
HHD5		91.09			339.16			2170.31
HHD6		91.75			202.76			2792.22
HHD7		80.55			188.10			3182.54
HHD8		33.19			126.22			1553.58
HHD9		75.08			341.34			3226.08
FGOVND					612.42			3519.88
FGOVD								83.79
FGOVI					0.00			92.68
SGOVNE					1982.44			5375.20
SGOVE		1736.05						1736.05
SGOVI		535.92			0.00			569.21
INV			0.00		335.24	2314.66	1858.96	9974.28
FT	2.44	82.99	66.00	3.73	165.75	0.00		4420.84
DT	-2.44	-82.99	-66.00	-3.73	-165.75			11551.94
TOTAL	92.68	5375.20	1736.05	569.21	9974.28	4420.84	11551.94	
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table B-5. Balanced SAM for the Palo Duro region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	430.07	0.24		0.40	0.23	1019.97	173.40	1.14
CONST-C	4.08	0.06	0.22	1.28	8.26	0.93	38.55	6.03
UTIL-C	18.91	1.13	58.89	7.97	19.68	10.29	89.40	11.46
TRAD-C	226.67	48.49	1.88	21.97	36.01	106.62	236.33	39.91
MIN-C	7.60	4.86	10.22	0.01	62.27	1.14	1553.49	0.51
FOOD-C	16.53			0.68		180.72	322.80	13.59
MAN-C	450.57	94.42	2.82	24.96	149.12	39.63	519.43	86.76
SER-C	123.35	40.53	21.69	213.63	394.03	235.08	396.49	472.61
MISC-C	181.96	5.88	2.02	41.63	15.30	8.43	29.71	77.86
LAB	167.22	148.90	17.29	170.60	261.74	175.73	263.18	652.15
CAP	599.60	96.74	34.19	113.02	315.18	52.71	620.81	280.08
INDT	-154.80	2.87	13.24	137.04	149.87	8.64	30.77	55.38
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	2071.76	444.12	162.46	733.21	1411.69	1839.88	4274.36	1697.49
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-5 Cont. Balanced SAM for the Palo Duro region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		2060.65						0.02
CONST-A			444.12					
UTIL-A				162.03		0.03		
TRAD-A					733.21			
MIN-A						1290.53		121.16
FOOD-A							1839.83	0.05
MAN-A						11.66	30.59	4229.57
SER-A		0.05			0.00	0.01		
MISC-A				21.97	1.57			
AGR-C	0.03							
CONST-C	24.67							
UTIL-C	4.65							
TRAD-C	5.50							
MIN-C	0.83							
FOOD-C	0.36							
MAN-C	9.93							
SER-C	85.39							
MISC-C	19.58							
LAB	29.38							
CAP	216.13							
INDT	31.03							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.13		0.00			0.00	
FGOVD								
FGOVI								
SGOVNE		1.64		0.38				
SGOVE								
SGOVI								
INV		55.12			0.12	7.20	0.50	3.02
FT		59.35		0.17		361.90	65.52	381.24
DT		565.09	30.50	95.91	458.94	597.89	407.80	1257.56
TOTAL	427.49	2742.02	474.62	280.45	1193.84	2269.22	2344.25	5992.62
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-5 Cont. Balanced SAM for the Palo Duro region

	SER-C	MISC-C	LAB	CAP	INDT	HHD1	HHD2	HHD3
AGR-A	11.09							
CONST-A								
UTIL-A		0.40						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	2.34	0.21						
SER-A	1697.22	0.19						
MISC-A	14.71	389.24						
AGR-C						0.68	1.39	1.34
CONST-C								
UTIL-C						2.19	4.35	3.92
TRAD-C						17.79	36.06	35.42
MIN-C						0.00	0.00	0.00
FOOD-C						7.17	13.00	12.85
MAN-C						9.76	21.23	21.05
SER-C						48.46	98.98	107.92
MISC-C						20.15	41.74	37.55
LAB								
CAP								
INDT								
HHD1		0.77	7.13	1.78		0.00	0.01	0.01
HHD2		1.48	47.36	18.89		0.01	0.04	0.05
HHD3		1.98	83.39	26.81		0.01	0.05	0.06
HHD4		2.03	105.89	34.50		0.02	0.07	0.07
HHD5		3.74	243.25	82.28		0.02	0.10	0.10
HHD6		4.69	353.86	121.35		0.04	0.16	0.17
HHD7		5.58	408.12	160.87		0.05	0.22	0.23
HHD8		3.12	201.08	81.26		0.04	0.15	0.16
HHD9		2.98	182.03	162.53		0.05	0.22	0.23
FGOVND		0.28	210.01	30.44	30.27	-1.41	-6.73	-2.21
FGOVD								
FGOVI		0.07						
SGOVNE	181.37	4.29	1.99	12.78	243.76	0.28	3.60	1.02
SGOVE								
SGOVI		5.61						
INV	0.01	0.75		1375.86				
FT	34.38	77.87		5.54		0.51	1.08	1.12
DT	1981.77	410.28	42.08	213.59		-0.51	-1.08	-1.12
TOTAL	3922.89	915.55	1886.18	2328.46	274.03	105.34	214.63	219.94
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-5 Cont. Balanced SAM for the Palo Duro region

	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND	FGOVD
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	1.16	1.99	2.39	2.43	0.91	0.66		0.00
CONST-C							0.01	0.19
UTIL-C	3.60	5.62	5.92	5.15	1.95	1.25	0.01	0.05
TRAD-C	33.33	56.81	64.02	66.49	26.91	19.36	0.03	0.37
MIN-C	0.00	0.00	0.00	0.00	0.00	0.00	0.01	
FOOD-C	11.53	18.35	20.10	19.83	6.90	4.77	0.00	0.09
MAN-C	18.72	32.65	36.18	38.10	16.35	10.59	0.09	1.59
SER-C	107.04	177.26	214.07	210.97	89.88	89.56	14.17	9.69
MISC-C	38.84	64.99	78.47	76.67	36.02	28.62	0.10	0.40
LAB								
CAP								
INDT								
HHD1	0.01	0.02	0.03	0.05	0.05	0.13	20.83	
HHD2	0.06	0.10	0.18	0.29	0.25	0.73	70.23	
HHD3	0.07	0.12	0.22	0.35	0.30	0.87	58.95	
HHD4	0.10	0.16	0.29	0.46	0.39	1.14	51.91	
HHD5	0.14	0.23	0.41	0.66	0.56	1.64	64.71	
HHD6	0.23	0.37	0.68	1.08	0.91	2.68	59.76	
HHD7	0.32	0.52	0.94	1.50	1.26	3.71	47.76	
HHD8	0.21	0.35	0.63	1.01	0.85	2.51	17.80	
HHD9	0.31	0.51	0.91	1.46	1.22	3.61	18.18	
FGOVND	5.23	28.30	52.69	82.72	53.33	85.63		
FGOVD							12.38	
FGOVI							11.66	
SGOVNE	1.06	23.00	7.10	4.40	6.13	8.69	85.58	
SGOVE								
SGOVI								
INV	0.36	19.98	101.27	163.57	92.44	146.03	106.13	
FT	1.09	1.83	2.15	2.06	0.82	0.63	0.01	0.10
DT	-1.09	-1.83	-2.15	-2.06	-0.82	-0.63	-0.01	-0.10
TOTAL	222.31	431.32	586.50	677.21	336.58	412.17	640.29	12.38
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B-5 Cont. Balanced SAM for the Palo Duro region

	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A								2071.76
CONST-A								444.12
UTIL-A								162.46
TRAD-A								733.21
MIN-A								1411.69
FOOD-A								1839.88
MAN-A								4274.36
SER-A								1697.49
MISC-A								427.49
AGR-C		1.75	0.08		1.09	137.40	963.28	2742.02
CONST-C	2.02	9.02	2.92	89.81	275.57	0.03	10.96	474.62
UTIL-C		3.92	2.08			0.66	17.41	280.45
TRAD-C	0.12	11.59	3.34	1.12	2.65	54.50	40.56	1193.84
MIN-C		0.32	0.05		53.98	204.79	369.12	2269.22
FOOD-C		14.47	4.38		0.82	168.55	1506.75	2344.25
MAN-C	0.39	38.46	15.16	1.70	492.07	466.98	3393.89	5992.62
SER-C	9.20	197.47	203.03	26.06	83.42	72.85	180.06	3922.89
MISC-C		10.73	1.45		52.07	27.50	17.88	915.55
LAB								1886.18
CAP								2328.46
INDT								274.03
HHD1		5.87			68.64			105.34
HHD2		21.45			53.50			214.63
HHD3		19.86			26.89			219.94
HHD4		15.91			9.40			222.31
HHD5		19.93			13.56			431.32
HHD6		18.33			22.20			586.50
HHD7		15.20			30.94			677.21
HHD8		6.33			21.09			336.58
HHD9		7.33			30.60			412.17
FGOVND					71.60			640.29
FGOVD					0.00			12.38
FGOVI								11.73
SGOVNE					176.47			763.52
SGOVE		232.48						232.48
SGOVI		113.09						118.70
INV	0.00		0.00	0.00	333.88			2406.24
FT	0.05	2.68	1.17	0.11	131.89	0.00		1133.26
DT	-0.05	-2.68	-1.17	-0.11	453.90			6499.90
TOTAL	11.73	763.52	232.48	118.70	2406.24	1133.26	6499.90	
DIFF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

- Create sets
  - FF (F) Production Factors
  - FFNW (FF) Production Factors without water
  - WATER (FF) Water
  - H (I) Households
  - G (I) Government Units
  - FG(G) Federal Government Units
  - SG (G) State Government Units
  - HG (I) Household and Government Units
- Set parameters
  - CAPCLOS Capital closure
  - LABCLOS Labor closure
  - LANDCLOS Land closure
  - WATERCLOS Water closure
  - SICLOS Savings investment closure
  - ROWCLOS Foreign savings closure
  - RUSCLOS RUS savings closure
  - xed(C,T) Elasticity of demand for world export function
  - esubp(A) Elasticity of substitution for production
  - esubd(C) Elasticity of substitution (armington) between regional output and imports
  - esubs(C) Elasticity of substitution (transformation) between domestic (regional) and foreign demand
  - esube(C) Elasticity of substitution (transformation) between row and rus for exports
  - esubm(C) Elasticity of substitution (armington) between row imports and rus imports
  - ine(C,H) Income elasticity
  - frisch(C) Consumption flexibility--determines minimum subsistence level of consumption -1 imples zero minimum
  - efac(FF) Demand elasticity for capital and labor
- Set closures
  - CAPCLOS = 2
    - Capital is mobile and supply is variable
  - LABCLOS = 3
    - Labor is mobile and unemployment is possible
  - SICLOS = 3
    - CPI changes
  - ROWCLOS = 3
    - Foreign savings (import – foreign savings imports) is variable
  - RUSCLOS = 2
    - RUS savings (import – imports RUS savings) is variable

- Set additional parameters
    - PMO(C) Initial import price (domestic currency)
    - XRO(T) Initial exchange rate
    - PEO(C) Initial export price (domestic currency)
    - PQO(C) Initial composite commodity price
    - PDO(C) Initial domestic price of domestic output
    - QQO(C) Initial quantity supplied to domestic commodity demanders
    - QMO(C) Initial quantity of imports
    - QDO(C) Initial quantity of domestic output sold domestically
    - PXO(C) Initial producer price
    - QXO(C) Initial quantity of domestic output
    - QEO(C) Initial quantity of exports
    - PAO(A) Initial activity price
    - PVAO(A) Initial value added price
    - QAO(A) Initial activity level
    - QFO(FF,A) Initial quantity demanded of factor FF by activity A
    - QINTO(C,A) Initial quantity of intermeditate use of commodity C by activity A
    - WFO(FF) Initial average wage or rental rate of factor FF
    - YFO(I,FF) Initial transfer of income to institution I from factor FF
    - YHO(H) Initial gross household income
    - NYHO(H) Initial net household income
    - QHO(C,H) Initial household comsumption
    - QINVO(C) Initial investment demand
    - QIINVO(I) Initial institutional investment
    - YFGO Initial federal government revenue
    - EFGO Initial federal government expenditures
    - YSGO Initial state government revenue
    - ESGO Initial state government expenditures
    - QFSO(FF) Initial factor supply
    - FSAVXO Initial exports foreign savings
    - DSAVXO Initial exports RUS savings
    - FSAVMO Initial imports foreign savings
    - DSAVMO Initial imports RUS savings
    - WFDISTO(FF,A) Initial distortion factor for factor FF in activity A
    - INDTO(G) Initial indirect taxes
    - IMAKEQO(I,C) Initial institutional make matrix (quantity)
    - QMRO(T,C) Initial regional imports
    - PMRO(T,C) Initial regional import price
    - QERO(C,T) Initial regional exports
    - PERO(C,T) Initial regional export price
    - PWEO(C,T) Initial world export price

- IADJO — Initial investment adjustment factor
- SADJO — Initial savings adjustment factor
- SGADJO — Initial state government adjustment factor for quantity purchased
- SHIFTFFO(FF) — Factor supply equation shift variable
- theta(A,C) — Yield of output C per unit of activity A
- ica(C,A) — Quantity of C as intermediate input per unit of activity A
- ad(A) — Production shift parameter
- del(F,A) — Production function share parameter
- rho(A) — CES production function exponent
- adel(C) — Armington commodity composite share parameter for production
- aq(C) — Armington commodity composite shift parameter
- arho(C) — Armington commodity composite exponent
- sdel(C) — Armington CET composite share parameter for domestic sales
- srho(C) — Armington CET composite exponent
- as(C) — Armington CET composite shift parameter
- edel(C) — Armington composite share parameter foreign exports
- erho(C) — Armington composite exponent for exports
- ae(C) — Armington composite shift parameter for exports
- mdel(C) — Armington composite share parameter foreign imports
- mrho(C) — Armington composite exponent for imports
- am(C) — Armington composite shift parameter for imports
- tc(C) — Consumption tax (only paid by households)
- tq(C) — Sales tax
- tqs(C) — Sales tax on services not previously taxed
- tm(T,C) — Import taxes
- te(C,T) — Export tax rate
- tb(A) — Indirect business tax rate
- mps(H) — Marginal propensity to save
- ty(G,H) — Rate of household income tax
- trh(H,HH) — Interhousehold transfers
- pwm(T,C) — ROW and RUS import price
- cwts(C) — weight of commodity C in the cpi
- CPIO — initial consumer price index
- wfa(FF,A) — wage for factor FF in activity A
- xshift(C,T) — Shift parameter for world export demand function
- lambda(C,H) — Subsistance level parameter
- beta(C,H) — Marginal budget share parameter
- engelwt(H) — Engel aggregation weight

- qg(C,G) — Government consumption
- shry(I,FF) — Instutional share of factor income
- tbshr(G) — Government unit share of indirect business taxes

- Set variables
    - PM(C) — Import price (domestic currency)
    - XR(T) — Exchange rate
    - PWE(C,T) — World export price
    - PE(C) — Export price (domestic currency)
    - PQ(C) — Composite commodity price
    - PD(C) — Domestic price of domestic output
    - PMR(T,C) — Regional price of imported commodities
    - PER(C,T) — Regional price of exported commodities
    - PA(A) — Activity price
    - PVA(A) — Value added price
    - PX(C) — Producer price
    - QQ(C) — Quantity supplied to domestic commodity demanders
    - QM(C) — Quantity of imports
    - QD(C) — Quantity of domestic output sold domestically
    - QMR(T,C) — Regional imports
    - QER(C,T) — Regional exports
    - QX(C) — Quantity of domestic output
    - QE(C) — Quantity of exports
    - QA(A) — Activity level
    - QF(FF,A) — Quantity demanded of factor FF by activity A
    - QINT(C,A) — Quantity of intermediate use of commodity C by activity A
    - WF(FF) — Average wage or rental rate of factor FF
    - YF(I,FF) — Factor income
    - YH(H) — Gross household income
    - NYH(H) — Net household income
    - QH(C,H) — Household consumption
    - QINV(C) — Investment demand
    - QIINV(I) — Investment demand by institutions
    - YFG — Federal government revenue
    - EFG — Federal government expenditure
    - YSG — State government revenue
    - ESG — State government expenditure
    - QFS(FF) — Factor supply
    - WALRAS — Dummy variable
    - IADJ — Investment adjustment variable
    - SADJ — Savings adjustment variable
    - SGADJ — State government spending adjustment variable for quantity purchased

- WFDIST(FF,A) Wage distortion factor
- INDT(G) Total indirect taxes
- IMAKEQ(I,C) Make matrix (quantity)
- SHIFTFF(FF) Factor supply equation shift variable
- FSAVX Exports foreign savings
- DSAVX Exports RUS savings
- FSAVM Imports foreign savings
- DSAVM Imports RUS savings
- CPI Consumer Price Index

- Set equations
  - PMDEFF(T,C) Regional foreign import price equation
  - PEDEFF(C,T) Regional foreign export price equation
  - PMDEFD(T,C) Regional domestic import price equation
  - PEDEFD(C,T) Regional domestic export price equation
  - WEXDEM(C,T) World export demand function
  - ARMIMP(C) Armington import composite equation
  - ROWRUSM(C) ROW-RUS import ratio
  - ROWRUSE(C) ROW-RUS export ratio
  - IMPVAL(C) Import output value
  - EXPVAL(C) Export output value
  - ARMEXP(C) Armington export composite equation
  - EQMRUS(C) Absorption equation for one imported commodity
  - EQERUS(C) Absorption equation for one exported commodity
  - EPERUS(C) Price for one exported destination
  - EPMRUS(C) Price for one imported destination
  - ABSORP(C) Absorption equation
  - DOMOUT(C) Domestic Output Value
  - PADEF(A) Activity price equation
  - PVADEF(A) Value added price
  - PRODN(A) Leontief-CES Production Functions
  - FACDEM(FFNW,A) Factor demand equation
  - FACDEMW(WATER,AG)
  - FACDEMWNA(WATER,ANA)
  - INTDEM(C,A) Intermediate input demand equation
  - ALLOC(C) Output function
  - ARMCOMS(C) Armington commodity composite supply equation
  - IMPDEM(C) Import-Domestic demand ratio
  - SUPNON(C) Composite supply for nonimported commodities
  - ARMCET(C) Output transformation CET equation
  - EXPDOM(C) Export-domestic supply ratio
  - OUTNON(C) Output transformation for nonexported commodities
  - FACINC(I,FF) Factor income
  - HOUSINC(H) Household income
  - NYHINCOME(H) Net household income

- HOUSDEM(C,H) Household consumption demand
- INVDEM(C) Investment demand equation
- FGOVREV Federal government revenue equation
- FGOVEXP Federal government expenditure equation
- SGOVREV State government revenue equation
- SGOVEXP State government expenditure equation
- SGOVBUD State government budget balanced
- FACMKT(FF) Factor market equation
- COMPMKT(C) Composite commodity market equation
- CURACCF ROW current account balance
- CURACCD RUS current account balance
- SAVBAL Savings investment balance
- NORM Price normalization equation
- INDTCALC(G) Indirect tax calculation
- FACSUP(FF) Factor supply equation

- Set model
  - MODEL CGEMODEL
    /
    PMDEFF
    PEDEFF
    PMDEFD
    PEDEFD
    WEXDEM
    ARMIMP
    ROWRUSM
    ROWRUSE
    IMPVAL
    EXPVAL
    ARMEXP
    EQMRUS
    EQERUS
    EPERUS
    EPMRUS
    ABSORP
    DOMOUT
    PADEF
    PVADEF
    PRODN
    FACDEM
    FACDEMW
    FACDEMWNA
    INTDEM
    ALLOC
    ARMCOMS
    IMPDEM

SUPNON
ARMCET
EXPDOM
OUTNON
FACINC
HOUSINC
NYHINCOME
HOUSDEM
INVDEM
FGOVREV
FGOVEXP
SGOVREV
SGOVEXP
SGOVBUD
FACMKT
COMPMKT
CURACCF
CURACCD
SAVBAL
NORM
INDTCALC
FACSUP
/;

- Initialize variables
- Set counterfactual
  - Example used to calibrate model
    - xshift('MANU-C','FT') = 1.0*xshift('MANU-C','FT')
- SOLVE CGEMODEL USING MCP:
  - Parameters:
    - UTO(H) — Base household utility
    - UT(H) — Household Utility
    - EV(H) — Equivalent Variation
    - IMPORTSO(T) — Base imports
    - IMPORTS(T) — Counterfactual imports
    - EXPORTSO(T) — Base exports
    - EXPORTS(T) — Counterfactual exports
    - GDPFCO — Base total wage and capital bill (GDP at factor cost)-- all the following based on Kendrick notes
    - GDPFC — Counterfactual wage and capital bill (GDP at factor cost)-- Kendrick notes
    - GDPMCO1 — Base state GDP (c + i + g + e - m) (GDP at market prices--Kendrick notes
    - GDPMC1 — Counterfactual state GDP (c + i + g + e – m) (GDP at market prices--Kendrick notes

        - GDPMCO2 — Base value added for economy (wage and capital bill plus indirect business taxes)—also = GDP at market prices?
        - GDPMC2 — Counterfactual value-added for economy (wage and capital bill plus indirect business taxes) --also = GDP at market prices
        - GDPMCO3 — Total activity output minus intermediate cost minus (ibt) equals total wage and capital bill
        - GDPMC3 — Counterfactual Total activity output minus intermediate cost minus (ibt) equals total wage and capital bill
    - Calculate descriptive parameters based on the output of the model
- Call the REPORT generator file (rename REPORT output file)

REPORT File

- Run by the MODEL file

SAM Modified File

- Copy of SAM file
- Add land and water to set K
- Create subset ANA(A) that is all activity accounts except AGR-A
- Create subset AG(A) that is only AGR-A
- Add land and water to set F(K)
- Add in all land and water values and update capital values
    - Calculated in PD_newsam_rased_modified Excel file
        - Activity columns to land row
            - AGR-A to LAND = 0.02 x AGR-A column total
                - 0.02 is the proportion of production value that goes towards land rental (proportion without water)
            - Other activity accounts = CAP / (1 + 2.3)
                - 2.3 is the ratio of capital / land
        - Activity columns to water row
            - AGR-A to WATER = 0.04 x AGR-A column total
                - 0.04 is the proportion of the agricultural land value with water
        - Activity columns to capital row
            - CAP – (LAND + WATER)
    - Calculated in DMF_newsam_rased_modified Excel file
        - Activity columns to land row
            - AGR-A to LAND = 0.08 x AGR-A column total
                - 0.08 is the proportion of production value that goes towards land rental (proportion without water)
            - Other activity accounts = CAP / (1 + 2.3)
                - 2.3 is the ratio of capital / land
        - Activity columns to water row
            - AGR-A to WATER = 0.04 x AGR-A column total
                - 0.04 is the proportion of the agricultural land value with water
        - Activity columns to capital row
            - CAP – (LAND + WATER)

Table B-6. Balanced SAM including land and water for the DMF region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	149.47	1.23		2.62	0.55	455.09	26.07	12.35
CONST-C	5.23	0.31	0.61	7.34	33.00	1.15	14.12	33.92
UTIL-C	8.40	5.73	486.95	50.04	47.45	12.10	40.29	108.93
TRAD-C	42.86	245.89	7.01	129.86	120.83	82.42	241.24	344.65
MIN-C	1.78	24.68	38.95	0.08	154.72	1.73	496.24	3.91
FOOD-C	1.12			2.81		197.39	46.26	160.76
MAN-C	94.06	480.03	12.79	146.43	458.67	81.64	978.21	743.89
SER-C	31.09	206.13	79.03	1291.50	1236.65	120.16	324.93	5032.22
MISC-C	48.26	29.90	7.95	283.10	43.29	7.42	37.01	892.72
LAB	191.48	537.99	141.64	1226.39	552.56	66.15	263.19	6680.30
CAP	184.91	283.77	196.82	517.17	375.80	63.34	184.72	1808.97
LAND	66.68	123.38	85.57	224.86	163.39	27.54	80.31	786.51
WATER	33.34							
INDT	-25.19	14.62	65.89	424.02	420.21	8.44	24.26	577.48
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	833.50	1953.66	1123.20	4306.21	3607.12	1124.57	2756.87	17186.60

Table B-6 Cont. Balanced SAM including land and water for the DMF region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		823.05						0.06
CONST-A			1953.66					
UTIL-A				1122.38		0.10		
TRAD-A					4306.21			
MIN-A						3403.72		203.40
FOOD-A							1110.94	13.63
MAN-A						3.87	3.86	2727.50
SER-A		0.22			0.01	0.09		
MISC-A				83.78	5.97			
AGR-C	0.46							
CONST-C	190.19							
UTIL-C	82.31							
TRAD-C	42.41							
MIN-C	3.46							
FOOD-C	5.56							
MAN-C	81.17							
SER-C	935.61							
MISC-C	334.36							
LAB	348.99							
CAP	1030.48							
LAND	448.03							
WATER								
INDT	238.12							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.54		0.03			0.01	
FGOVD								
FGOVI								
SGOVNE		11.22		2.61				
SGOVE								
SGOVI								
INV		28.57			0.40	13.24	1.05	1.19
FT		71.31		1.16		269.20	121.58	1888.19
DT		434.92	47.46	140.97	492.76	65.44	1077.00	4320.75
TOTAL	3741.16	1369.83	2001.12	1350.93	4805.36	3755.66	2314.45	9154.72

Table B-6 Cont. Balanced SAM including land and water for the DMF region

	SER-C	MISC-C	LAB	CAP	LAND	WATER	INDT	HHD1
AGR-A	10.38							
CONST-A								
UTIL-A		0.72						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	20.35	1.28						
SER-A	17184.81	1.47						
MISC-A	57.31	3594.09						
AGR-C								5.83
CONST-C								
UTIL-C								18.75
TRAD-C								151.91
MIN-C								0.01
FOOD-C								61.28
MAN-C								83.38
SER-C								413.95
MISC-C								172.13
LAB								
CAP								
LAND								
WATER								
INDT								
HHD1		6.60	50.76	7.26	3.63	0.17		0.02
HHD2		10.02	264.97	33.05	16.53	0.78		0.06
HHD3		10.80	367.54	42.87	21.43	1.01		0.07
HHD4		11.15	478.12	60.28	30.14	1.42		0.09
HHD5		20.96	1118.82	124.25	62.12	2.93		0.13
HHD6		28.13	1750.15	200.92	100.45	4.73		0.23
HHD7		34.10	2101.11	273.54	136.76	6.45		0.32
HHD8		18.48	999.49	155.01	77.50	3.65		0.22
HHD9		32.98	1683.92	517.65	258.80	12.20		0.58
FGOVND		2.21	1063.73	71.62			220.68	-8.60
FGOVD								
FGOVI		0.54						
SGOVNE	1161.19	29.42	10.58	34.07			1527.17	1.42
SGOVE								
SGOVI		33.29						
INV	1.04	3.30		2987.51	1298.92			
FT	287.07	339.08		17.25				61.63
DT	5265.39	893.04	119.52	120.69				-61.63
TOTAL	23987.55	5071.66	10008.71	4645.97	2006.27	33.34	1747.86	901.77

Table B-6 Cont. Balanced SAM including land and water for the DMF region

	HHD2	HHD3	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND
AGR-A									
CONST-A									
UTIL-A									
TRAD-A									
MIN-A									
FOOD-A									
MAN-A									
SER-A									
MISC-A									
AGR-C	9.41	7.31	6.38	11.14	14.35	14.84	5.41	7.28	
CONST-C									0.10
UTIL-C	29.53	21.36	19.82	31.51	35.55	31.52	11.51	13.81	0.06
TRAD-C	244.93	192.90	183.44	318.75	384.32	406.52	159.27	213.87	0.24
MIN-C	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.08
FOOD-C	88.31	70.00	63.45	102.95	120.70	121.22	40.82	52.74	0.00
MAN-C	144.20	114.68	103.02	183.16	217.21	232.97	96.78	117.00	0.79
SER-C	672.31	587.77	589.10	994.50	1285.15	1289.92	532.05	989.58	119.62
MISC-C	283.52	204.53	213.78	364.63	471.06	468.76	213.21	316.22	0.81
LAB									
CAP									
LAND									
WATER									
INDT									
HHD1	0.07	0.07	0.10	0.16	0.29	0.47	0.39	1.16	174.73
HHD2	0.27	0.28	0.38	0.63	1.14	1.82	1.53	4.50	505.30
HHD3	0.28	0.29	0.40	0.65	1.17	1.88	1.58	4.65	341.14
HHD4	0.37	0.39	0.52	0.86	1.55	2.48	2.09	6.15	305.72
HHD5	0.54	0.57	0.77	1.26	2.28	3.64	3.06	9.03	389.71
HHD6	0.95	1.01	1.36	2.23	4.03	6.44	5.41	15.96	375.70
HHD7	1.35	1.43	1.92	3.15	5.69	9.09	7.65	22.54	308.82
HHD8	0.90	0.95	1.28	2.10	3.78	6.05	5.09	14.99	104.70
HHD9	2.41	2.55	3.42	5.63	10.16	16.24	13.66	40.26	209.20
FGOVND	-29.65	-8.17	19.97	109.79	220.49	356.06	226.16	662.58	
FGOVD									83.79
FGOVI									92.14
SGOVNE	8.04	2.62	2.67	37.17	13.29	9.01	8.82	26.22	507.23
SGOVE									
SGOVI									
INV						203.59	219.10	707.52	
FT	98.88	70.89	89.38	148.86	214.66	183.60	69.79	163.59	0.60
DT	-98.88	-70.89	-89.38	-148.86	-214.66	-183.60	-69.79	-163.59	-0.60
TOTAL	1457.75	1200.55	1211.77	2170.31	2792.22	3182.54	1553.58	3226.08	3519.88

Table B-6 Cont. Balanced SAM including land and water for the DMF region

	FGOVD	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A									833.50
CONST-A									1953.66
UTIL-A									1123.20
TRAD-A									4306.21
MIN-A									3607.12
FOOD-A									1124.57
MAN-A									2756.87
SER-A									17186.60
MISC-A									3741.16
AGR-C	0.00		11.51	0.53		0.29	294.45	333.26	1369.83
CONST-C	1.26	15.85	66.67	19.69	397.73	1196.87	0.15	16.93	2001.12
UTIL-C	0.36		31.80	14.03			4.20	244.92	1350.93
TRAD-C	2.50	0.94	100.50	22.49	6.63	17.10	343.93	797.94	4805.36
MIN-C			2.30	0.33		233.98	375.89	2417.39	3755.66
FOOD-C	0.60		127.46	29.53		2.31	82.95	936.24	2314.45
MAN-C	10.74	3.10	310.38	102.16	10.12	2139.05	286.67	1922.41	9154.72
SER-C	65.62	72.79	1698.79	1537.54	154.73	348.40	534.29	2844.15	23987.55
MISC-C	2.72		74.97	9.74		228.20	183.63	179.75	5071.66
LAB									10008.71
CAP									4645.97
LAND									2006.27
WATER									33.34
INDT									1747.86
HHD1			40.65			615.23			901.77
HHD2			116.23			500.25			1457.75
HHD3			79.27			325.52			1200.55
HHD4			71.05			239.39			1211.77
HHD5			91.09			339.16			2170.31
HHD6			91.75			202.76			2792.22
HHD7			80.55			188.10			3182.54
HHD8			33.19			126.22			1553.58
HHD9			75.08			341.34			3226.08
FGOVND						612.42			3519.88
FGOVD									83.79
FGOVI						0.00			92.68
SGOVNE						1982.44			5375.20
SGOVE			1736.05						1736.05
SGOVI			535.92			0.00			569.21
INV	0.00			0.00		335.24	2314.66	1858.96	9974.28
FT	3.22	2.44	82.99	66.00	3.73	165.75	0.00		4420.84
DT	-3.22	-2.44	-82.99	-66.00	-3.73	-165.75			11551.94
TOTAL	83.79	92.68	5375.20	1736.05	569.21	9974.28	4420.84	11551.94	

Table B-7. Balanced SAM including land and water for the Palo Duro region

	AGR-A	CONST-A	UTIL-A	TRAD-A	MIN-A	FOOD-A	MAN-A	SER-A
AGR-A								
CONST-A								
UTIL-A								
TRAD-A								
MIN-A								
FOOD-A								
MAN-A								
SER-A								
MISC-A								
AGR-C	430.07	0.24		0.40	0.23	1019.97	173.40	1.14
CONST-C	4.08	0.06	0.22	1.28	8.26	0.93	38.55	6.03
UTIL-C	18.91	1.13	58.89	7.97	19.68	10.29	89.40	11.46
TRAD-C	226.67	48.49	1.88	21.97	36.01	106.62	236.33	39.91
MIN-C	7.60	4.86	10.22	0.01	62.27	1.14	1553.49	0.51
FOOD-C	16.53			0.68		180.72	322.80	13.59
MAN-C	450.57	94.42	2.82	24.96	149.12	39.63	519.43	86.76
SER-C	123.35	40.53	21.69	213.63	394.03	235.08	396.49	472.61
MISC-C	181.96	5.88	2.02	41.63	15.30	8.43	29.71	77.86
LAB	167.22	148.90	17.29	170.60	261.74	175.73	263.18	652.15
CAP	475.30	67.43	23.83	78.77	219.67	36.73	432.68	195.21
LAND	41.44	29.32	10.36	34.25	95.51	15.97	188.12	84.87
WATER	82.87							
INDT	-154.80	2.87	13.24	137.04	149.87	8.64	30.77	55.38
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND								
FGOVD								
FGOVI								
SGOVNE								
SGOVE								
SGOVI								
INV								
FT								
DT								
TOTAL	2071.76	444.12	162.46	733.21	1411.69	1839.88	4274.36	1697.49

Table B-7 Cont. Balanced SAM including land and water for the Palo Duro region

	MISC-A	AGR-C	CONST-C	UTIL-C	TRAD-C	MIN-C	FOOD-C	MAN-C
AGR-A		2060.65						0.02
CONST-A			444.12					
UTIL-A				162.03		0.03		
TRAD-A					733.21			
MIN-A						1290.53		121.16
FOOD-A							1839.83	0.05
MAN-A						11.66	30.59	4229.57
SER-A		0.05			0.00	0.01		
MISC-A				21.97	1.57			
AGR-C	0.03							
CONST-C	24.67							
UTIL-C	4.65							
TRAD-C	5.50							
MIN-C	0.83							
FOOD-C	0.36							
MAN-C	9.93							
SER-C	85.39							
MISC-C	19.58							
LAB	29.38							
CAP	150.64							
LAND	65.50							
WATER								
INDT	31.03							
HHD1								
HHD2								
HHD3								
HHD4								
HHD5								
HHD6								
HHD7								
HHD8								
HHD9								
FGOVND		0.13		0.00			0.00	
FGOVD								
FGOVI								
SGOVNE		1.64		0.38				
SGOVE								
SGOVI								
INV		55.12			0.12	7.20	0.50	3.02
FT		59.35		0.17		361.90	65.52	381.24
DT		565.09	30.50	95.91	458.94	597.89	407.80	1257.56
TOTAL	427.49	2742.02	474.62	280.45	1193.84	2269.22	2344.25	5992.62

Table B-7 Cont. Balanced SAM including land and water for the Palo Duro region

	SER-C	MISC-C	LAB	CAP	LAND	WATER	INDT	HHD1
AGR-A	11.09							
CONST-A								
UTIL-A		0.40						
TRAD-A								
MIN-A								
FOOD-A								
MAN-A	2.34	0.21						
SER-A	1697.22	0.19						
MISC-A	14.71	389.24						
AGR-C								0.68
CONST-C								
UTIL-C								2.19
TRAD-C								17.79
MIN-C								0.00
FOOD-C								7.17
MAN-C								9.76
SER-C								48.46
MISC-C								20.15
LAB								
CAP								
LAND								
WATER								
INDT								
HHD1		0.77	7.13	1.19	0.38	0.21		0.00
HHD2		1.48	47.36	12.56	4.06	2.27		0.01
HHD3		1.98	83.39	17.83	5.76	3.22		0.01
HHD4		2.03	105.89	22.94	7.42	4.14		0.02
HHD5		3.74	243.25	54.71	17.69	9.88		0.02
HHD6		4.69	353.86	80.69	26.09	14.57		0.04
HHD7		5.58	408.12	106.97	34.59	19.31		0.05
HHD8		3.12	201.08	54.03	17.47	9.76		0.04
HHD9		2.98	182.03	108.07	34.94	19.51		0.05
FGOVND		0.28	210.01	30.44			30.27	-1.41
FGOVD								
FGOVI		0.07						
SGOVNE	181.37	4.29	1.99	12.78			243.76	0.28
SGOVE								
SGOVI		5.61						
INV	0.01	0.75		958.93	416.93			
FT	34.38	77.87		5.54				0.51
DT	1981.77	410.28	42.08	213.59				-0.51
TOTAL	3922.89	915.55	1886.18	1680.26	565.33	82.87	274.03	105.34

Table B-7 Cont. Balanced SAM including land and water for the Palo Duro region

	HHD2	HHD3	HHD4	HHD5	HHD6	HHD7	HHD8	HHD9	FGOVND
AGR-A									
CONST-A									
UTIL-A									
TRAD-A									
MIN-A									
FOOD-A									
MAN-A									
SER-A									
MISC-A									
AGR-C	1.39	1.34	1.16	1.99	2.39	2.43	0.91	0.66	
CONST-C									0.01
UTIL-C	4.35	3.92	3.60	5.62	5.92	5.15	1.95	1.25	0.01
TRAD-C	36.06	35.42	33.33	56.81	64.02	66.49	26.91	19.36	0.03
MIN-C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
FOOD-C	13.00	12.85	11.53	18.35	20.10	19.83	6.90	4.77	0.00
MAN-C	21.23	21.05	18.72	32.65	36.18	38.10	16.35	10.59	0.09
SER-C	98.98	107.92	107.04	177.26	214.07	210.97	89.88	89.56	14.17
MISC-C	41.74	37.55	38.84	64.99	78.47	76.67	36.02	28.62	0.10
LAB									
CAP									
LAND									
WATER									
INDT									
HHD1	0.01	0.01	0.01	0.02	0.03	0.05	0.05	0.13	20.83
HHD2	0.04	0.05	0.06	0.10	0.18	0.29	0.25	0.73	70.23
HHD3	0.05	0.06	0.07	0.12	0.22	0.35	0.30	0.87	58.95
HHD4	0.07	0.07	0.10	0.16	0.29	0.46	0.39	1.14	51.91
HHD5	0.10	0.10	0.14	0.23	0.41	0.66	0.56	1.64	64.71
HHD6	0.16	0.17	0.23	0.37	0.68	1.08	0.91	2.68	59.76
HHD7	0.22	0.23	0.32	0.52	0.94	1.50	1.26	3.71	47.76
HHD8	0.15	0.16	0.21	0.35	0.63	1.01	0.85	2.51	17.80
HHD9	0.22	0.23	0.31	0.51	0.91	1.46	1.22	3.61	18.18
FGOVND	-6.73	-2.21	5.23	28.30	52.69	82.72	53.33	85.63	
FGOVD									12.38
FGOVI									11.66
SGOVNE	3.60	1.02	1.06	23.00	7.10	4.40	6.13	8.69	85.58
SGOVE									
SGOVI									
INV			0.36	19.98	101.27	163.57	92.44	146.03	106.13
FT	1.08	1.12	1.09	1.83	2.15	2.06	0.82	0.63	0.01
DT	-1.08	-1.12	-1.09	-1.83	-2.15	-2.06	-0.82	-0.63	-0.01
TOTAL	214.63	219.94	222.31	431.32	586.50	677.21	336.58	412.17	640.29

Table B-7 Cont. Balanced SAM including land and water for the Palo Duro region

	FGOVD	FGOVI	SGOVNE	SGOVE	SGOVI	INV	FT	DT	TOTAL
AGR-A									2071.76
CONST-A									444.12
UTIL-A									162.46
TRAD-A									733.21
MIN-A									1411.69
FOOD-A									1839.88
MAN-A									4274.36
SER-A									1697.49
MISC-A									427.49
AGR-C	0.00		1.75	0.08		1.09	137.40	963.28	2742.02
CONST-C	0.19	2.02	9.02	2.92	89.81	275.57	0.03	10.96	474.62
UTIL-C	0.05		3.92	2.08			0.66	17.41	280.45
TRAD-C	0.37	0.12	11.59	3.34	1.12	2.65	54.50	40.56	1193.84
MIN-C			0.32	0.05		53.98	204.79	369.12	2269.22
FOOD-C	0.09		14.47	4.38		0.82	168.55	1506.75	2344.25
MAN-C	1.59	0.39	38.46	15.16	1.70	492.07	466.98	3393.89	5992.62
SER-C	9.69	9.20	197.47	203.03	26.06	83.42	72.85	180.06	3922.89
MISC-C	0.40		10.73	1.45		52.07	27.50	17.88	915.55
LAB									1886.18
CAP									1680.26
LAND									565.33
WATER									82.87
INDT									274.03
HHD1			5.87			68.64			105.34
HHD2			21.45			53.50			214.63
HHD3			19.86			26.89			219.94
HHD4			15.91			9.40			222.31
HHD5			19.93			13.56			431.32
HHD6			18.33			22.20			586.50
HHD7			15.20			30.94			677.21
HHD8			6.33			21.09			336.58
HHD9			7.33			30.60			412.17
FGOVND						71.60			640.29
FGOVD						0.00			12.38
FGOVI									11.73
SGOVNE						176.47			763.52
SGOVE			232.48						232.48
SGOVI			113.09						118.70
INV		0.00		0.00	0.00	333.88			2406.24
FT	0.10	0.05	2.68	1.17	0.11	131.89	0.00		1133.26
DT	-0.10	-0.05	-2.68	-1.17	-0.11	453.90			6499.90
TOTAL	12.38	11.73	763.52	232.48	118.70	2406.24	1133.26	6499.90	

Model Modified File

- Copy of Model File
- Read in SAM Modified file
- Add land and water into set LL and set MM
- Add land and water into set FF
- Create subset FFNW(FF) to include all factors except water
- Create subset WATER(FF) with just water
- Add equations
    - QFO('LAND',A) = SAM('LAND',A);
    - QFO('WATER',A) = SAM('WATER',A);
- Update wfa equation to add condition formatting to eliminate values of zero
    - wfa(FF,A)$QFO(FF,A)   = SAM(FF,A)/QFO(FF,A);
- Add equations for FACDEMW and FACDEMWNA
    - FACDEMW('WATER','AGR-A')..
      WFDIST('WATER','AGR-A')*WF('WATER') =E=
      PVA('AGR-A') * (ad('AGR-A')/(1-tb('AGR-A')-SUM(C, ica(C,'AGR-A'))))
      * (SUM(FFF, del(FFF,'AGR-A')*QF(FFF,'AGR-A')**(-rho('AGR-A'))))
      **((-1/rho('AGR-A'))-1)
      * del('WATER','AGR-A')*QF('WATER','AGR-A')**(-rho('AGR-A')-1);
    - FACDEMWNA(WATER,ANA)..
      QF(WATER,ANA)=E= 0;
- Add FACDEMW and FACDEMWNA into MODEL
- Add closures for land and water and set based on counterfactual
    - Land
        - EQ 2: mobile and supply is variable
        - EQ 3: activity-specific and fixed
    - Water
        - EQ 1: fully employed and mobile and supply is fixed
- Set counterfactual
    - Baseline: Depletion
        - PD
            - QFS.FX('WATER') = 0.2856*QFSO('WATER');
        - DMF
            - QFS.FX('WATER') = 0.5912*QFSO('WATER');
        - A weighted average of status quo saturated thickness based on irrigated acreage for Hansford, Hartley, and Moore counties of the PD region and Hockley and Lynn counties of the DMF region was calculated

        - A baseline shock was calculated by = 1 – (beginning saturated thickness – ending saturated thickness) / beginning saturated thickness
    - Scenario 1: Water reduction policy of 10 percent
        - PD
            - QFS.FX('WATER') = 0.3218*QFSO('WATER');
        - DMF
            - QFS.FX('WATER') = 0.6221*QFSO('WATER');
        - A weighted average of saturated thickness with a 10 percent reduction in irrigated acres based on irrigated acreage for Hansford, Hartley, and Moore counties of the PD region and Hockley and Lynn counties of the DMF region was calculated
        - A shock for the 10 percent reduction in water was calculated by = 1 – (beginning saturated thickness – ending saturated thickness) / beginning saturated thickness
    - Scenario 2: Water reduction policy of 10 percent with a 10 percent reduction of land
        - PD
            - QFS.FX('WATER') = 0.3218*QFSO('WATER');
            - QF.FX('LAND','AGR-A') = 0.9*QFO('LAND','AGR-A');
        - DMF
            - QFS.FX('WATER') = 0.6221*QFSO('WATER');
            - QF.FX('LAND','AGR-A') = 0.9*QFO('LAND','AGR-A');
    - Scenario 3: Baseline depletion with technology changes
        - PD
            - QFS.FX('WATER') = 0.2856*QFSO('WATER');
            - del('WATER','AGR-A') = 0.9*del('WATER','AGR-A');
            - ALIAS (FFNW,FFNW2);
              parameter share (FFNW, AG);
              share (FFNW,AG)=
              del(FFNW,AG)/sum(FFNW2,del(FFNW2,AG));
              display share;
              *$exit
            - del(FFNW,AG)=(1-del('WATER',AG))*share(FFNW,AG);
              display del;
              *$exit
        - DMF
            - QFS.FX('WATER') = 0.5912*QFSO('WATER');
            - del('WATER','AGR-A') = 0.9*del('WATER','AGR-A');
            - ALIAS (FFNW,FFNW2);
              parameter share (FFNW, AG);

share (FFNW,AG)=
del(FFNW,AG)/sum(FFNW2,del(FFNW2,AG));
display share;
*$exit

- del(FFNW,AG)=(1-del('WATER',AG))*share(FFNW,AG);
  display del;
  *$exit

  - The scenario 3 code is taking the share of del without water and proportioning it out among the non-water factors then using those proportions to recalculate the share of del for the non-water factors according to the new share of water (Math shown in Technology share calculations Excel file)

- Update the name of the report before running each scenario in the code
- Comment out scenarios not being run

REPORT File

- Run by MODEL Modified File
- Code unchanged between original and modified MODEL code

REPORT Output File

- QF of LAB (employment)
  - If LBR = YES in the model code then it will track the actual number of jobs from the IMPLAN employment data
  - If LBR = NO in the model code then it will not use the employment data from IMPLAN and instead will be set to the numbers in the SAM
- Equivalent Variation = welfare
- The sum of the differences in factor returns (adjusted for indirect business taxes) should equal the difference in GDP
  - This shows the breakdown of what is being the most affected
- WALRAS dummy variable should be zero if the model is calibrating