# 2004 National IMPLAN User's Conference

Proceedings of the Conference (contains papers received by March 13, 2005)

October 6-8, 2004

Eastern Management Development Center

Sheperdstown, West Virginia

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Contributed Papers

**2004 NATIONAL IMPLAN USER'S CONFERENCE**

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**Sean Becker (sbecker@artsmarket.com)** **Pages 1-10**

## The Impact of Film Production on the Montana Economy & a Proposed Incentive for the Film Industry

On-location filmmakers have been coming to Montana for over 100 years, taking pictures and leaving money. Montana was a very popular location for filmmakers throughout the 70's, 80's and 90's. In the late 90's Canada and other foreign countries began offering financial incentive to film the same projects just over the border. Montana began losing film projects, and the positive economic impact that went with them. Recently other states have begun offering similar incentives and Montana's economy has suffered as more of the on-location production goes elsewhere.

This report has been written to illustrate the positive impacts of the film industry on Montana's economy. It also contains a proposal for an incentive that Montana can offer to the film industry in order to bring production back to Montana, and millions of new dollars into the economy.

Over the last five years the film industry has generated:

- $53 million in production related spending, resulting in an $81.4 million impact on Montana's economy
- 930 full time equivalent job in the film industry and 444 jobs indirectly, through the spending of new money in the economy
- $4.3 million dollars of tax revenue for Montana

This report proposes a three-part tax incentive based on production company expenditures on Montana labor, total production expenditures excluding labor, and an incentive for investing in films shot in Montana. The direct result of this incentive would be:

- A significant increase in film production in Montana (similar programs in nearby states have shown 300% growth in the first year)
- Millions of new dollars into the economy, creating greater economic output
- Montana jobs created that would not exist without the incentive
- Graduates of Montana's university film programs being able to find employment in Montana.

**Jared Creason** (creason.jared@epamail.epa.gov) **Pages 11-18**

**Costs of Improved Water Quality Standards in the Chesapeake Bay**

At the request of EPA's Chesapeake Bay Program, the EPA National Center for Environmental Economics (NCEE) evaluated the potential socioeconomic impact of developing revised water quality criteria, designated uses, and boundaries for the Chesapeake Bay and its tidal waters. NCEE estimated the direct and indirect effects of compliance using peer- reviewed economic models of the affected sectors in Bay watershed. Economic and social impacts evaluated include changes employment, wages, income, and the value of regional output, or goods produced.

**Jared Creason, Susan F Stone, Isabelle Morin, Michael Fisher**
**(benglish@utk.edu)** **Pages 19-28**

Emission Coefficients for Implan Models

It is not clear, *a priori*, how larger scale economic events affect local environmental conditions. On the one hand, a policy or regulation with a large economic effect does not necessarily have large environmental impacts. On the other hand, a policy change may have small economic impacts, but large environmental impacts. Thus, determining if any economic change, large scale or local, will ultimately have a significant environmental impact, is largely an empirical question.

In order to help answer that empirical question, the EPA commissioned Abt Associates to build the Trade and Environmental Assessment Model, or TEAM. While the TEAM acronym refers to 'Trade' as the source of change, the model can be used to analyze the environmental impact of any economic change. The environmental effects are based on economic output changes derived from data at the 6-digit NAICS level, covering over 1,200 sectors at the county level. The economic data may be aggregated to the IMPLAN sector scheme, producing a means of easily converting economic changes at the county level to projected impacts.

TEAM reports outcomes for over 900 chemicals covering four broad emissions/resource use categories: water (use, direct and indirect discharges), air (point source, mobile source and area source), agriculture (land use and chemical use) and hazardous waste.

The paper discusses the distribution of the effects both across sectors, and across counties in the United States. It also presents the limitations of such an analysis, including the linear nature of the model.

**Burton C. English, R. Jamey Menard, Bradley S. Wilson, Daniel De La Torre Ugarte** (benglish@utk.edu) Pages **38-47**

**Integrating IMPLAN with a National Agricultural Policy Model**

Economic impacts resulting from national policy changes can be evaluated using state IMPLAN models. Numerous publications have taken results from a national model and used those results in showing what impacts would occur to a state or a region's economy. However, what happens when you wish to take the impacts from an interregional multi-state model that is national in scope to examine the potential impacts changes in policy has on the nation's economy? An option explored in this proposed paper is an interface developed between POLYSYS, a 330 agricultural supply region econometric model, and IMPLAN. The interface takes POLYSYS acreage, price, and cost output and makes two major types of changes to IMPLAN databases. First, the program adds an energy crop sector to IMPLAN based on production and cost information supplied by the POLYSYS results for each of the 48 contiguous states. Next, agricultural impacts that occur as a result of projected changes in the agricultural sectors are placed in each state IMPLAN model incorporating POLYSYS projected changes in crop production, prices, and income.

The integrator, written in Visual Basic and taking advantage of IMPLAN's data structure, provides the user a means to solve IMPLAN at the state level and determine regional economic impacts as a result of changes in agricultural production practices, policies, prices, government payments, and/or technology adoption. The resulting reports generated from the analysis summarize, via graphs and maps, the economic impacts as measured by changes in total industry output, employment, and value added. In addition, tabular information is presented for use in the analysis.

**Kim Jensen, Burton C. English, R. Jamey Menard, Marie E. Walsh, Craig C. Brandt, James W. Van Dyke, Stan W. Hadley (kjensen@utk.edu)** 

**Direct, Indirect, and Induced Impacts from Co-Firing Biomass Feedstocks in Southeastern United States Coal-Fired Plants**

Economic impacts of using biomass in Southeast U.S. coal-fired plants are estimated using a county-level biomass database; ORCED, a dynamic electricity distribution model that estimates feedstock value; ORIBAS, a GIS model that estimates feedstock transportation costs, and IMPLAN, an input-output model that determines the impacts of co-firing on economic activity.

This study examines the economic impacts of co-firing biomass feedstocks (forest residues, primary mill residues, agricultural residues, dedicated energy crops, and urban wood wastes) with coal in coal-fired power plants in the Southeastern United States (AL, GA, KY, MS, NC, SC, TN, VA). The impacts of using each type of feedstock are evaluated for three emission credit and two co-firing level combinations.

Analysis using IMPLAN involved several steps that modified the base IMPLAN data. For each feedstock, modification to identified sectors' production functions were made to accommodate the flow harvest, transportation and power generation facility modifications required for co-firing. Following the modifications, multipliers for each identified sector was generated and then used to determine total industry output, employment, and value-added impacts. Losses as a result of decreases in coal demand were estimated by impacting those regions where coal is mined.

Biomass feedstocks do not appear competitive under the current environment except under certain situations and under low co-fire levels. Very small amounts of biomass are economically feasible for co-fire in the Base Case. However, under two percent co-fire, some plants can purchase biomass feedstocks at a lower cost than coal plus sulfur emissions costs. The analysis indicates that there are areas now that would benefit from generating electricity using forest residues, mill waste, and urban wood waste. Nearly 817 gigawatt hours (Gwh) of electricity are produced using these biomass feedstocks replacing 355,000 tons of coal.

## David B. Field (field@umenfa.maine.edu) Pages 48-52

**Using IMPLAN for Forest Policy Analysis in Maine**

This paper reviews three small, practical applications of IMPLAN to forest policy issues in Maine. Maine, the most heavily forested state in the nation, where 96 percent of the timberland is privately owned, has seen significant shocks to its forestry sector in recent years that have leant themselves to policy analysis. In the first application, the Maine Bureau of Public Lands was planning to harvest timber. The paper mills were paying more for low-grade softwood logs than were the sawmills, but decision makers wondered if the multiplier effects of lumber manufacture would be greater than for paper making, favoring a decision in the public interest that would be less profitable for the agency. In the second case, concerns over the future of the paper industry prompted an analysis of impacts on the state's economy, as well as the economy of a county where the industry is particularly influential, of significant changes in the paper sector. The third, and most recent application, has involved estimating the impacts of the Federal Government's quotas on H2B foreign workers on Maine, where the long-standing traditional use of Canadian woods workers is of great importance to the health of the forestry sector of the State's economy.

## Brad Gentner (brad.gentner@noaa.gov) Pages 53-65

**Using Stated Preference Choice Experiments to Forecast the Economic Impacts of Recreational Fishing Policies.**

The National Marine Fisheries Service (NMFS) is mandated by law to analyze the benefits, costs, and economic impacts of the recreational fisheries policies it promulgates. NMFS has developed single species models that predict welfare and effort changes stemming from changes in various recreational regulations. Little is known, however, about angler switching behavior between species in the face of these same policy changes. That is, as regulations are tightened for one species do those anglers quit fishing entirely or switch to a substitute species with less stringent regulations? Estimating these relationships requires specialized data collections involving long-term panel studies to gauge revealed preferences or the presentation of hypothetical scenarios to elicit stated preferences. NMFS is currently pursuing the latter; conducting a stated preference mail survey that presents anglers a series of choice scenarios that vary in quality, policy, and species target attributes, and asks them to choose a preferred trip. Species included in the scenarios include grouper, red snapper, king mackerel, and dolphin fish. This data collection will field surveys monthly through August 2004 using anglers sampled during the Marine Recreational Fisheries Statistical Survey (MRFSS) creel survey and the MRFSS random digit dial survey of coastal households in the South Atlantic and Gulf Coast states of the US. This paper presents the preliminary results of the stated preference survey, including a random utility model that examines the substitution of target species under different policy scenarios.

**Knut I. Westeren, Anwar Hussain and Wilbur R. Maki (wmaki@mn.rr.com)**


SAM for Puerto Rico Regions—Measuring Regional Employment and Income Impacts of Market Growth and Change in Puerto Rico's Basic Industries

The purpose of the SAM for Puerto Rico is to measure and monitor regional employment and income impacts of changing markets and federal subsidies, or the lack of them, for the Commonwealth's basic industries. The existing SAM modeling system for Puerto Rico still lacks important industry detail available for US counties. The SAM models must address the regional job and income impacts of the loss of business subsidies and export markets as well as the counter-balancing influence of new business startups among Puerto Rico's basic industries. This paper starts with a review of Puerto Rico's current input-output data systems based on an updating of a 1992 input-output model of 94 sectors. Next we describe regional impacts of changes in federal subsidies and market outlets for a region's industries under given scenarios of regional growth and development and access to the new local and regional data sources from federal agencies. Results suggest that Puerto Rico regions are largely exports-deficient, depending directly or indirectly on various subsidies to support existing business enterprise.

**Aaron K. Lusby (alusby@agecon.ksu.edu)**


**How Does Highway Infrastructure Investment Affect Oklahoma's Economic Development: A Computable General Equilibrium**

The purpose of this research is to determine how gross state product and other measures of welfare change when public investment in highway infrastructure is increased in Oklahoma. Policymakers need to know how improvements in the road system affect the economy. This leads to the ultimate research question: how do improvements in road infrastructure affect regional economic development? Answering this question could provide policymakers with better information for deciding whether to improve the road system. This research uses a dynamic computable general equilibrium model of the Oklahoma economy to determine economic development impacts in Oklahoma from different exogenous levels of public investment in road infrastructure measured through changes in gross state product, household income levels, state employment, and rental rates of private capital during a twenty year time period. A social accounting matrix constructed from IMPLAN data forms the base year equilibrium. Over the twenty years, gross regional product and private capital income declined relative to benchmark levels, while labor income, enterprise income, and disposable household income rose above benchmark levels. At the end of the period, the state experiences a net gain in labor and private capital, as workers and private capital migrated into the state. While the model could be improved, results indicate that investment in transportation infrastructure has a small, beneficial effect on the economy for workers, firms and households.

## Wilbur R. Maki (wmaki@mn.rr.com) Pages 92-105

**Using IMPLAN to Monitor Economic Change in Rural Areas of Egypt and Puerto Rico**

Egypt and Puerto Rico were selected as case studies, given the availability of comparable data series and issues to address. The positive changes addressed result in higher levels of regional employment and income and reduced levels of poverty. We discuss two sets of tools for measuring these changes. The first set extends the work of two groups of scholars focusing on Egypt's economy, starting with a social accounting model prepared by associates of the International Food and Policy Research Institute and continuing with a three-sector model prepared by Professors Mellor and Ranade that simulates income consequences of various policy options. The regional IMPLAN-SAM modeling systems for Egypt and Puerto Rico discussed elsewhere in this Conference provide a second set of tools focusing on rural development outcomes. This paper reviews the regional IMPLAN-SAM modeling system as a powerful and yet readily understood tool for monitoring rural development outcomes and their impacts on rural economies and people.

## Chester J. Pankowski (pankowski@email.wcu.edu) Pages 106-117

Economic Impact of Seven of the Eleven Member Organizations of Marketing Association of Rehabilitation Centers

Community rehabilitation centers in mountain communities of western North Carolina provide vocational training, pre-vocational services, employment, and community placement for individuals with disabilities. In an attempt to demonstrate their contribution to the local economy, an association of eleven community rehabilitation centers asked the Center for Regional Development (CRD) at Western Carolina University to conduct an economic impact analysis of their facilities. Using IMPLAN software and database, the CRD has been conducting an economic impact analysis of each rehabilitation center. Methodology employed involves reviewing each rehabilitation center's most recent completed fiscal year budget to identify operational and capital improvement expenditures made for goods and services purchased locally and wages paid. Employees that live and work in the local economy were identified by checking ZIP Codes on payroll records. Local employee wages are combined into groups of salary ranges, and expendable employee incomes are then estimated to be included in the IMPLAN analysis. Once dollar figures for local operational and capital improvement expenditures and employee expendable incomes have been estimated, dollar figures are entered into an IMPLAN model of the county(s) served by that community rehabilitation center. The IMPLAN model then generates a total economic impact on the local area in terms of dollars and jobs created. In addition, an estimate of sales tax revenue is made based on dollar spending by income range according to the most recent Bureau of Labor Statistics, Consumer Expenditures Report. After the IMPLAN work has been completed and tax revenues estimated, a report is written for use by the community rehabilitation center.

Jiyoung Park, Peter Gordon, James E. Moore II, Harry W. Richardson (jiyoungp@usc.edu)


**Construction of a U.S. Multiregional Input-Output Model Using IMPLAN**

A major problem in developing integrated interregional-intrametropolitan models is how to combine not easily compatible databases. This research aims to create a new National Interstate Economic Model (NIEMO) for the U.S., based on IMPLAN and related data for 2001. Constructing NIEMO is challenging because of the limited availability of commodity freight shipment data between the U.S. states. This explains why a NIEMO-type model has not been developed in recent years, in fact not since Polenske (1980). To construct NIEMO, two basic sets of tables along "Chenery-Moses" lines must be generated: the first are the regional tables that provide intra-regional industry coefficients by state, the second are the interregional trade tables to estimate trade coefficients by states and industry. The IMPLAN Professional Program (Version 2.0) is the basis for the regional tables. The trade tables (between all 50 States plus D.C. and the rest of the world) are assembled via the Fratar Model using the 1997 Commodity Flow Survey (CFS) data. Reconciliation of the IMPLAN and CFS databases present several problems that are addressed in this paper.

**Benedict C. Posadas (benp@ext.msstate.edu)** 

**Potential Economic Impact of Commercial Offshore Aquaculture in the Gulf of Mexico**

The Gulf of Mexico commercial offshore aquaculture industry would include the production, processing and distribution of aquaculture species. The use of cages to grow food fish in the Gulf waters had been a subject to recent research efforts and commercial ventures. Three-inch red drum fingerlings were raised to market-size fish in less than 12 months in a research project off Freefort, Texas. The Gulf of Mexico Offshore Aquaculture Consortium attempted to grow cobia from in an experimental cage 40 km off Pascagoula, Mississippi. The overall goal of this paper was to estimate the potential economic impact of the establishment of economically viable commercial offshore aquaculture production systems in the Gulf. The potential impact of the industry was estimated by using IMPLAN and the 2000 Gulf states data which facilitated the use of the most appropriate multipliers. Commercial offshore aquaculture production was represented by the "Miscellaneous livestock " sector. Commercial seafood processing was represented by the "Prepared Fresh or Frozen Fish or Seafood" sectors. The ex-vessel values of the Gulf commercial fishing and processing sectors were retrieved from the National Marine Fisheries Service database. The direct effects created by the establishment and operation of a single production system with 12 cages would generate indirect and induced effects. Indirect effects consist of the inter-industry effects of the input-output analysis. Induced effects consist of the impact of household expenditures in input-output analysis. The sum of the direct, indirect, and induced effects is equal to the total economic impact measured in terms of output ($), jobs, labor income ($), and tax collections ($).

**Martin T. Ross, Robert H. Beach, and Brian C. (rbeach@rti.org)** **Pages 151-168**

General Equilibrium Assessment of Regional Climate Change Policy

Analyses of options to mitigate global climate change generally concentrate on national policies. However, there has been growing interest in developing and implementing climate policy at the state and regional level within the U.S., particularly in the Northeast. This paper examines the economic implications of relying on regional approaches to climate change mitigation rather than broader national policies. We use the Applied Dynamic Analysis of the Global Economy (ADAGE) model, a multi-region intertemporally-optimizing computable general equilibrium modeling system, to compare the cost and distributional effects of several different mitigation policies. The U.S. component of the ADAGE model relies on state-level IMPLAN data integrated with detailed energy data from the Energy Information Administration and aggregated to five U.S. regions to generate a balanced social accounting matrix. The model solves in 5-year increments from 2005 through 2050. Standard optimization techniques are used to match Annual Energy Outlook forecasts for GDP, output, consumption, investment, and government spending in the baseline while minimizing changes needed in the economic data to maintain a balanced SAM in all years. A nested constant-elasticity-of-substitution model structure is used to portray the substitution possibilities available to producers and consumers. Our results highlight the effects on energy markets and other key sectors most directly affected by greenhouse gas (GHG) emissions limits. Our findings suggest that the comprehensiveness of a GHG mitigation plan is of vital importance in determining the costs of achieving a given mitigation target, and we provide estimates of the magnitudes of various inefficiencies. In addition, model results reveal substantial distributional effects of GHG policies across households and regions.

David Mulkey, Tom Stevens, and Alan W. Hodges (mbelyeu@ulf.edu) Pages 169-196

**IMPLAN Based Impact Modeling for Commercial Fisheries on Florida's East Coast: Alternative Approaches and Recommendations**

Alternative approaches to developing IMPLAN models that will allow the National Marine Fisheries Service (NMFS) to more quickly and accurately evaluate the economic impacts of regulatory changes for Florida's east-coast commercial fishing industry are explored in this paper. Current federal legislation requires NMFS to conduct such impact analyses whenever new regulations are developed and implemented. Procedures involved: (1). Reviewing Florida's east-coast commercial fishing industry in terms of its various production and processing technologies, as well as product distribution and market channels. (2). Evaluating the adequacy of the standard IMPLAN databases and sectoring scheme with respect to this fishery; (3). Determining what additional data are available for modifying and expanding IMPLAN's modeling capability for the fishery; (4). Reviewing previous work in other regions on customizing IMPLAN models for fishing industry impacts. and; (5.) Making recommendations for adjustments and enhancements to standard IMPLAN models in terms of the number and nature of fishing related sectors at state or sub-state regional levels. Preliminary findings indicate that significant differences occur in the production, processing and distribution for many of the various species of fish harvested along Florida's east coast. These difference are primarily defined by species, harvesting gear-type, and less so by spatial differences within the state. Cost and effort data, newly available through the South Atlantic Fishery Management Council, in

combination with landings and revenues data available by species and location through the Florida Fish and Wildlife Conservation Commission, make it feasible to disaggregate IMPLAN's single fishing sector (No. 16) and seafood processing and packaging sector (No. 71) into multiple customized sectors that specifically capture the technology and product flows of enterprises developed around species groups.

**Wei Tu and Daniel Z. Sui (wtu@georgiasouthern.edu)** **Pages 197-233**

**The Dynamic Transformation of Regional Economy of Texas in the 1990s: A GIS-Based Economic Modeling and Analysis**

This paper discusses the dynamic economic structure change in thirteen regions of Texas through a new analytic framework based on the integration of Geographic Information Systems (GIS), Input-Output (IO) analysis, and extended shift-share analysis. The research is set within the context of the emergence of the digital economy and information society in the U.S. The regional economic transformation was analyzed and mapped on the basis of three-segment IO models for the years 1990, 1994, and 1999. It was found that 1) the information segment increased much faster than production and energy segments; 2) in order to produce one unit of output, relatively more inputs from the information segment, but less inputs from the production and energy segments were required; 3) there existed clear spatial growth differentiation and segment specialization in Texas in the 1990s. The integration of GIS and IO analysis and shift-share analysis has proved to be not only an efficient way of managing the data, but also an effective tool to model and map spatial economic activities. The results also indicate that Texas economy has been less material/energy-dependent but more information-dependent during the 1990s. More thorough studies are expected to highlight environmental consequences of the change in the future.

# The Impact of Film Production on the Montana Economy & a Proposed Incentive for the Film Industry

Presented by **Sean Becker** for the Montana Film Office, Montana Department of Commerce and Artsmarket (www.artsmarket.com; staff@artsmarket.com)

## I. Introduction

The film industry is considered extremely valuable in most state's economies because on-location filming acts as a "supercharged" source of new dollars that wouldn't otherwise flow into the state economy. On-locations filming includes large commercial and smaller budget films, documentaries, educational/industrial films/videos, TV and print commercials, music videos, distance learning and all related work that is done on location in the state. The film industry brings in outside dollars, which then re-circulate through the economy. Films shot on location in any state also serve as a promotion for that state, and indeed, films such as *A River Runs Through It* and *The Horse Whisperer*, alongside TV commercials and documentaries, have all contributed to building a positive image of Montana.

The movement of new business into the state economy may also be leveraged, at least in part, because of the visibility that films give to the state, its scenery and communities.

There are other impacts from a healthy on-location film industry that states seek. Chief among them is the intellectual capital that comes from having a year-round creative industry working within the state. Montana's university film programs are able to place graduates in jobs in Montana, and in return those businesses bring the out-of-state film industry back to the state to produce films and commercials. This maintains the education-to-jobs cycle. The industry is non-polluting, non-extractive and is also valued because it creates an enhanced quality of life through related programming such as film festivals that can enhance quality of life in communities.

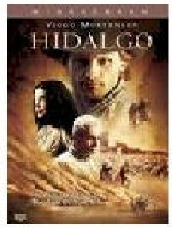
It is also an industry that can on nearly a moment's notice breathe life into communities that need jobs and revitalization. When a film is made in a community, many workers are able to obtain employment, buildings are painted, empty warehouses are rented, hotel rooms and restaurants are filled, carpenters build sets, and huge infusions of new purchases for materials and services are made locally.

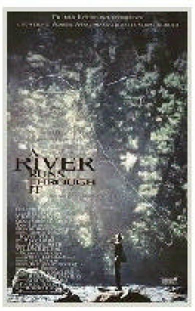
The investment of new film industry dollars mainly comes from out of state as well as from out of the country. Most film and commercial dollars flow into the state from either Los Angeles or New York, and increasingly from foreign investors. These dollars, which can mean anywhere from hundreds of thousands of new dollars a day to as much as $35 million over six months for a major on-site shoot, would not otherwise come into the state.

It is because of this range of economic benefits that many states have become highly competitive in seeking increased on-location filming. Many states have implemented highly effective tax incentives for the film industry. Some states, such as Louisiana, Illinois, and New Mexico, have recently taken the lead on increasing the direct on-site industry impact to their states by as much as 300% percent or more. Others are currently studying ways to gain their share of the business. Offshore, or so-called runaway film production, benefits are increasingly being realized by Canadian provinces, Australia, New Zealand, Central Europe and many and other countries. The province of Alberta, for example, offers a substantial benefits package to film producers who seek Canada's look-alike version of Montana.

# Partial list of movies filmed in Montana

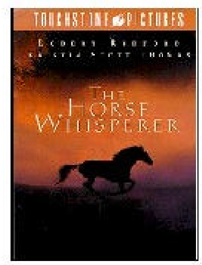
1. **Hidalgo**
2. **What Dreams May Come**
3. **Beethoven's 2nd**
4. **Forrest Gump**
5. **The River Wild**
6. **Always**
7. **Disorganized Crime**
8. **The Shining**
9. **Cattle Queen of Montana**
10. **Red Skies of Montana**
11. **The Patriot**
12. **Return To Lonesome Dove**
13. **Diggstown**
14. **Thousand Pieces of Gold**

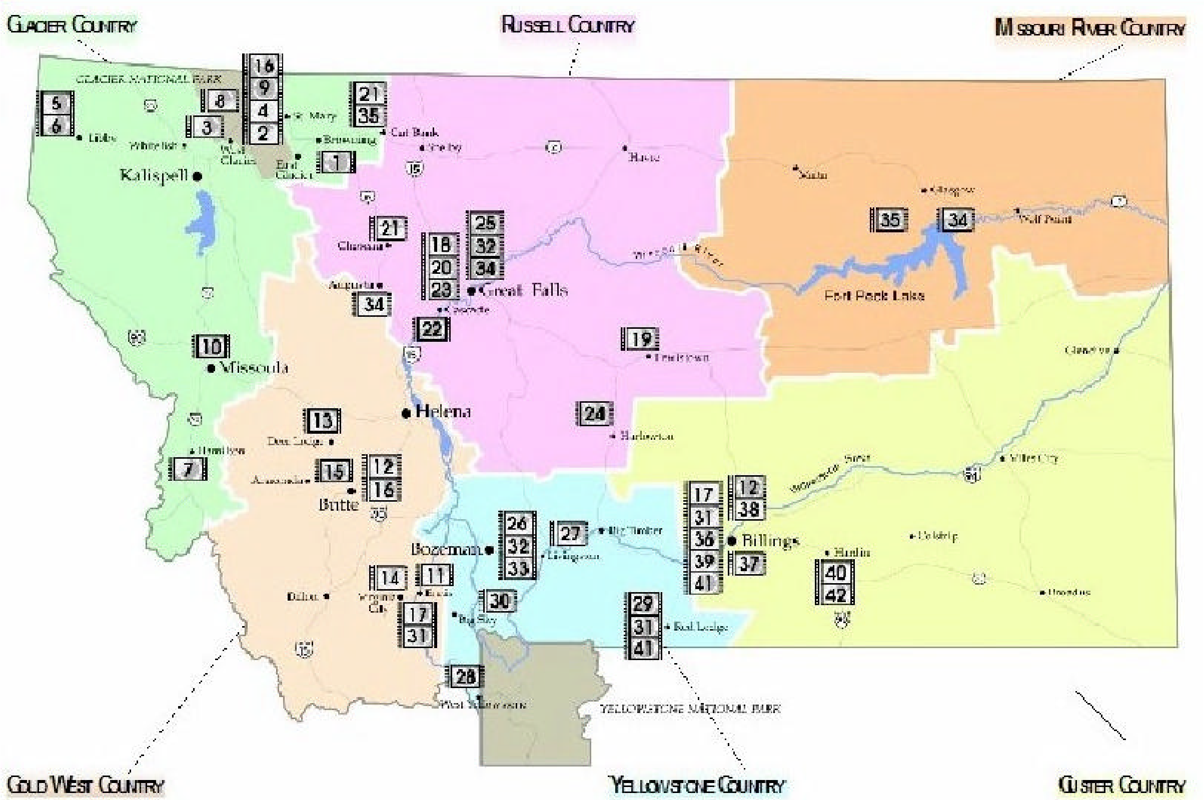



15. **Runaway Train**
16. **Heaven's Gate**
17. **Little Big Man**
18. **The Slaughter Rule**
19. **Broken Arrow**
20. **Holy Matrimony**
21. **War Party**
22. **The Untouchables**
23. **The Stone Boy**
24. **Heartland**
25. **Telefon**
26. **Everything That Rises**
27. **The Horse Whisperer**
28. **Iron Will**

29. **The Ballad of Little Jo**
30. **A River Runs Through It**
31. **Missouri Breaks**
32. **Thunderbolt and Lightfoot**
33. **Rancho Deluxe**
34. **Northfork**
35. **Firefox**
36. **Josh and S.A.M.**
36. **Far and Away**
38. **Son of the Morning Star**
39. **Bright Angel**
40. **Pow Wow Highway**
41. **The Legend of Walks Far Woman**
42. **Warpath**



## II. Methodology

This report was commissioned by the Montana Film Office to document the impacts of the film industry on the state, drawn from actual data from 1998-2003. This report was prepared by ArtsMarket, Inc., a Bozeman economic and research firm that provides economic studies of the creative and cultural industries and sectors.

The researchers developed a series of budget models for each type of on-location production based on actual data provided to the Montana Film Office. 444 documented film projects were produced in Montana over the last 5 years. The Montana Film Office surveys each of these productions to determine their expenditures in Montana. Fifteen percent of the producers answered the survey sent to them regarding their production expenditures in Montana. The budget models were developed from this data. In addition, these models were reviewed by some of Montana's leading film producers for their accuracy in reflecting the range of impacts and size of productions that could be expected in any typical year.

The researchers worked with the actual number of reported on-site productions (444), and applied the analysis model to these. The researchers created the cumulative impact of the on-site industry from 1998-2003, the years for which data was available. The economic, employment and tax impacts of these actual productions were evaluated by production type and by year. The Micro IMPLAN system was used to further assess all the impacts of the direct expenditures.

Please note that there are more productions taking place every year on-site than are reported to the Film Office, particularly more commercials and other smaller budget productions. And, in the case of all productions, on-site costs as given are conservative compared to national norms.

Questions concerning this study can be directed to Sten Iversen, Manager of the Montana Film Office, at sten@visitmt.com or to Sean Becker, Research Director with ArtsMarket, Inc at sbecker@artsmarket.com.

## III. Economic Impact of the Film Industry on Montana's Economy

### DIRECT IMPACT

In any given week, a film crew will be landing at a Montana airport, renting cars, and heading out to location. They will be hiring local crew, doing post-production work on-site, and making purchases often of significant construction and other materials.

For a TV commercial spot for a new car or truck, the on-site work may be done in a few days to a week. A documentary may work on-site for a week. A major feature film that has a brief Montana setting may be on-site for a few weeks. And a film in which Montana plays a prominent role may set up on location for months at a time, often with months of preparation in advance.

Through records maintained by the Film Office, it has been possible to create sound, conservative models of each type of production, at each level of production – from low budget entries to major name production films. These expenditures as presented here are exceedingly conservative as compared to what would be seen in other, more costly states.

Direct economic impacts will represent just a portion of the total economic impact of attracted or retained off-site spending as we have seen from the previous sections. The total impact for every type of production also includes a multiplier effect. This multiplier effect occurs as off-site spending at restaurants, hotels, retail outlets or other businesses re-circulates throughout the Montana economy. For example, crews will purchase set supplies and materials on-site rather than truck or fly them in from out of state. This will require additional spending by local businesses, professional services and any other type of good or services necessary to supply the industry. This means additional jobs for Montana far beyond the direct boundaries of the film expenditures.

At the same time, employees of restaurants, stores and other businesses will be earning additional money, and spending that money as part of their daily lives at the grocery stores and shopping malls, as well as for expenses such as healthcare, insurance and rent or mortgage payments. This results in additional jobs and wages throughout the economy. These extra sales, jobs and earnings are part of the "multiplier effect," and should be added to the direct effect to calculate the total economic impact of attracted or retained off-site spending.

The Micro IMPLAN model[1] was used to calculate the economic multipliers and tax impacts of the film production industry on the state of Montana.

Impact of Film Operating Expenditures[2]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[1] The Micro IMPLAN model can be used to generate a set of multipliers for more than 500 industries in any state or group of counties in the United States. The data set used to determine the following numbers was based upon Montana's data. Based on Montana input-output tables, the Micro IMPLAN model generates a complete model of a state economy based on the unique industrial structure of the state and trade flows into and out of the state. This model of the state economy is used to calculate economic multipliers that can be combined with measures of output such as expenditures or consumer spending to estimate a direct, indirect (multiplier effect) and total economic impact.

[2] Calculated from models based upon actual reported production budgets.

**TABLE 1: Summary of Film Production Impacts on Montana over a 5 year period (1998-2003)**

| Direct Impact (Input) | Indirect and Induced Impacts [3] | Total Impact (Output)[4] |
|---|---|---|
| $52,968,500 | $28,466,500 | $81,435,000 |

**TABLE 2: SUMMARY OF ECONOMIC IMPACTS BY PRODUCTION TYPE OVER 5 YEARS (1998 – 2003)**

| Summary of Impacts | Direct Impact (Input) | Indirect and Induced Impacts | Total Impact (Output) |
|---|---|---|---|
| Commercials | $19,085,000 | $10,140,000 | $29,225,000 |
| Documentaries | $2,103,500 | $1,083,500 | $3,187,000 |
| Edu/Industrial Film | $369,000 | $179,000 | $548,000 |
| Feature Films | $14,100,000 | $7,388,000 | $21,488,000 |
| Music Videos | $513,000 | $257,000 | $770,000 |
| Short Films | $262,000 | $134,000 | $396,000 |
| Still Shots | $5,873,000 | $3,110,000 | $8,983,000 |
| TV Impacts | $10,663,000 | $6,175,000 | $16,838,000 |
| TOTAL OF IMPACTS | $52,968,500 | $28,466,500 | $81,435,000 |

[3] Indirect Effects: Represents the response by all local industries caused industries purchasing from industries per million dollars of final demand for a given industry. (Film production related business spending)
Induced Effects: Represents the response by all local industries caused by the expenditures of new household income generated by the direct and indirect effects per million dollars of final demand for a given industry. (Spending by employees of film production related businesses)

[4] Industry output is a single number in dollars for each industry or industry model. The dollars represent the value of an economic model's total production. The data were derived from a number of sources, including Bureau of Census economic census, Bureau of Economic Analysis output estimates and the U.S. Bureau of Labor Statistics employment projections.

## TABLE 3: SUMMARY OF ECONOMIC IMPACTS BY YEAR

| Year of Productions | Direct Impact (Input) | Indirect and Induced Impacts | Total Impact (Output) |
|---|---|---|---|
| **1998** | $7,574,000 | $4,078,000 | $11,652,000 |
| 1999 | $14,106,000 | $7,628,500 | $21,734,500 |
| 2000 | $8,542,500 | $4,562,000 | $13,104,500 |
| 2001 | $6,120,500 | $3,333,500 | $9,454,000 |
| 2002 | $10,906,500 | $5,842,500 | $16,749,000 |
| **2003** | $5,719,000 | $3,022,000 | $8,741,000 |
| **TOTAL** | $52,968,500 | $28,466,500 | $81,435,000 |

## TABLE 4: SUMMARY OF EMPLOYMENT BY PRODUCTION TYPE OVER 5 YEARS (1998-2003)

| **Summary of Impacts** | Direct Employment F.T.E.[5] | Indirect and Induced Employment F.T.E. | TOTAL Employment F.T.E. | Total Worker Income[6] |
|---|---|---|---|---|
| Commercials | 308 | 147 | 455 | $8,683,000 |
| Documentaries | 35 | 17 | 52 | $997,000 |
| Edu / Industry Film | 6 | 3 | 9 | $162,000 |
| Feature Films | 232 | 110 | 342 | $7,055,000 |
| Music Videos | 9 | 4 | 13 | $235,000 |
| Short Films | 4 | 2 | 6 | $112,000 |
| Still Shots | 106 | 50 | 156 | $2,884,000 |
| TV Impacts | 231 | 110 | 341 | $6,145,000 |
| TOTAL OF IMPACTS | 930 | 444 | 1,374 | $26,273,000 |

[5] F.T.E. = Full time equivalent employment

[6] Worker income is wage and salary payments as well as benefits, including: health and life insurance, retirement payments and any other non-cash compensation. It includes all income to workers paid by employers. Data comes from U.S. Department of Labor (ES202) employment security data supplemented by county business patterns (CPB) and Regional Economic Information System (REIS) data.

**TABLE 5: SUMMARY OF EMPLOYMENT BY YEAR**

| Year of Productions | Direct Employment **F.T.E.** | Indirect and Induced **Employment F.T.E.** | TOTAL Employment F.T.E. | Total Worker Income |
|---|---|---|---|---|
| **1998** | 133 | 64 | 197 | $3,735,000 |
| 1999 | 251 | 119 | 370 | $7,001,000 |
| 2000 | 146 | 70 | 216 | $4,171,000 |
| 2001 | 113 | 54 | 167 | $3,075,000 |
| 2002 | 190 | 91 | 281 | $5,506,000 |
| **2003** | 97 | 46 | 143 | $2,785,000 |
| **TOTAL** | 930 | 444 | 1,374 | $26,273,000 |

**TABLE 6: PERCENT OF PRODUCTION EXPENDITURES INTO MONTANA BUSINESSES BY PRODUCTION TYPE**

| Expenditure Area | Percent of Direct Production Expenditures[7] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Commercial | Documentary | Educational / Industrial | Feature Film | Music Video | Short Film | Still Shot | Television | TOTAL EXPENDITURES |
| Percentage of expenditures by production type | 36% | 4% | 1% | 27% | 1% | 0% | 11% | 20% | 100% |
| Labor | 25% | 22% | 24% | 13% | 33% | 36% | 12% | 12% | $9,403,510 |
| Actors | 6% | 10% | 8% | 5% | 10% | 20% | 5% | 1% | $2,593,950 |
| Hotel / Lodging | 12% | 12% | 16% | 12% | 7% | 8% | 17% | 31% | $8,654,470 |
| Equipment / Fuel | 11% | 15% | 12% | 25% | 11% | 2% | 20% | 2% | $7,433,685 |
| Props | 6% | 4% | 3% | 11% | 4% | 3% | 4% | 0% | $3,054,610 |
| Craft | 1% | 2% | 1% | 1% | 15% | 1% | 4% | 1% | $798,730 |
| Catering | 6% | 5% | 11% | 7% | 5% | 7% | 11% | 12% | $4,247,445 |
| Rental Cars | 6% | 4% | 4% | 3% | 2% | 8% | 7% | 8% | $2,962,370 |
| Lumber / Construction | 7% | 15% | 4% | 14% | 7% | 0% | 3% | 14% | $5,345,155 |
| Studio | 0% | 0% | 11% | 1% | 0% | 0% | 0% | 0% | $181,590 |
| Post-Production | 12% | 0% | 4% | 0% | 0% | 0% | 0% | 0% | $2,304,960 |
| Security | 2% | 2% | 1% | 3% | 2% | 0% | 5% | 5% | $1,687,520 |
| Location Fee | 5% | 9% | 1% | 5% | 3% | 15% | 10% | 12% | $3,773,805 |
| Film Processing | 1% | 0% | 0% | 0% | 1% | 0% | 2% | 2% | $526,700 |
| | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | $52,968,500 |

[7] Calculated from actual reported production budgets.

# IV. Tax Impacts on the Montana Economy

There are four primary data sources used to calculate the matrices that describe the state, local and federal tax impacts of a particular economic model. The data is examined by industry and aggregated to produce an overall impact. The data sources are the National Income and Product Accounts (NIPA), Consumer Expenditure Surveys (CES), Annual Survey of State and Local Government Finances (SCGF) and Regional Economic Information System data (REIS). The following is a more detailed breakdown of the data definitions.

National Income and Product Accounts (NIPA)

All data used in the impact analysis is affected by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA) NIPA values. The main elements that are applicable to the tax impact analysis are the Survey of Current Business, Personal Tax and Non-Tax Receipts, Indirect Business Tax and Non-Tax Accruals, Contributions for Social Insurance, Federal Governments Receipts and Current Expenditures, plus the controls for State and Local Government Receipts and Current Expenditures.

**Consumer Expenditure Surveys (CES)**

The U.S. Census Bureau collects an ongoing survey of individual household expenditure patterns. This data is used by the Bureau of Economic Analysis (BEA) to benchmark consumption patterns that are implemented in the National Income and Product Accounts (NIPA). This information establishes the tax to income ratio for nine different income groups. Using the number of households in each category affected by a given impact it is possible to calculate the state/local and Federal tax values for as small of an area as a single county.

**Annual Survey of State and Local Government Finances (SCGF)**

The U.S. Census Bureau's collection of state and local government receipts and expenditure data is used to control local tax values and the detailed relationships between government agencies and 500+ industries that may or may not be present in a given analysis.

**Regional Economic Information System Data (REIS)**

REIS data on income, wealth, tax and employment are collected by the Bureau of Economic Analysis (BEA) and applied to regional, state and local economies. The key REIS data for the tax impact analysis comes from the Personal Income by Major Source and Earnings by Industry and also the Personal Tax and Non-tax Payments tables (Tables CA05 & SA50, respectively from the BEA).

DIRECT PRODUCTION EXPENDITURE TAX IMPACTS

Tax impact reports are generated by IMPLAN after the economic impact model has been created. The major assumption of this analysis is that which is true for the economy of interest as a whole, is true for isolated elements of an economy; worded more precisely, it is assumed the derivation of predictive multipliers for a local economy holds true for marginal changes. We are examining the impact of on-site work by producers making films in Montana, not a global analysis of the entire economy and its gross output

# Emission Coefficients for Implan Models

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*The views expressed in this paper are those of the authors and are not endorsed by the US Environmental Protection Agency. Data and methods used in this paper have not be subjected to the Agency's internal or external review process and no endorsement is given or implied.*

## 1 BACKGROUND

Executive Order 13141 of November 16, 1999 requires the U.S. Trade Representative, through the interagency Trade Policy Staff Committee (TPSC), to conduct environmental reviews of trade agreements. The Trade Representative has the authority to determine whether an environmental review is warranted based on the significance of foreseeable environmental impacts. The U.S. Environmental Protection Agency, a member of the TPSC, is committed to working with the U.S. Trade Representative and the other members to assess how changes in economic activity resulting from trade agreements may affect domestic environmental quality.

EPA has previously developed a number of analytic frameworks for assessing the environmental effects of specific regulations and other actions affecting individual pollutant media (e.g., water pollutant discharges), or for assessing the broader environmental concerns of a particular industry. However, EPA lacked an analytic framework that was capable of addressing, in a comprehensive and consistent fashion, the environmental effects of trade agreements or other complex economic events potentially affecting a wide range of industries and environmental media throughout the country. To be able to assess environmental effects of trade agreements, EPA, with support from Abt Associates Inc., undertook development of a comprehensive assessment tool, the Trade and Environmental Assessment Model (TEAM). TEAM's objective is to provide EPA with a framework to assess the environmental implications of economic changes in general, and trade agreements in particular.

TEAM has the ability to assess environmental effects associated with a wide range of environmental media, including the following environmental release and resource use categories:

- Air emissions (point, area and mobile sources)
- Water discharges (direct and indirect)
- Hazardous waste generation
- Agricultural chemical release
- Land use
- Water use.

TEAM uses the recently adopted North American Industrial Classification System (NAICS) at the 6-digit level of resolution as the economics framework for analysis.

TEAM has the ability to capture environmental effects at a high degree of geographic resolution. To meet these objectives, EPA sought to use the affected production entity (e.g., manufacturing facility), where possible as the basics vocational unit of analysis for assessing environmental effects.

TEAM applies an Input-Output framework. Input-output analysis seeks to understand, at a specified level of economic sectoral and regional resolution, the framework and quantities of economic inputs that are required to produce economic outputs. Consistent with the input-output conceptual framework, TEAM treats environmental releases and resource use as though they were explicit factor inputs in the production of the economic goods and services that may be affected by a trade agreement. Specifically, TEAM is built around emission factors that describe the relationship between economic value of production, by economic sector and location, and the quantity of environmental releases and resource use that occur in conjunction with the production activity. These emission factors are conceptually equivalent to input-output coefficients in the traditional economic input-output framework.[1] These emission factors are defined as the physical quantity of directly produced pollutant emissions per dollar of output.

TEAM's emission factors are based on environmental release and resource use inventories compiled by EPA, the U.S. Department of Agriculture, and the U.S. Geological Survey coupled with economic activity data compiled from the U.S. Economic Census, the U.S. Agricultural Census, the U.S. Department of Energy, and certain private sources of economic data. These data underlie TEAM's emission factors and also describe the baseline profile of economic activity and environmental releases/resource use from which TEAM's estimated changes in environmental release and resource use are calculated. The model brings together these usually separate data characterizing domestic economic activity and environmental releases and resource uses, into a single consistent framework, in terms of time period, economic sector classification, and geography. EPA is aware of no other analytic system that combines these detailed data regarding the level of economic activity with associated emissions and resource use characteristics in an integrated analytic framework.

TEAM's emission factors differ from the more common concept of emission factor as used in environmental engineering analyses by being defined in relation to the economic value of output – quantity of pollutant emissions or resource use per dollar value of output – instead of in relation to a physical unit of operation or production.

TEAM uses the concept of total requirements analysis to understand the total economic and total resource/resource use effects of changes in production levels in primary impact sectors. TEAM can use a total requirements matrix derived from the U.S. Input-Output Accounts to convert a set of production changes in primary impact sectors into changes throughout all sectors and thus account for both he direct and indirect economic sector linkages to the primary impact sectors. In this case, the resource/resource use effects estimated by TEAM become total sector effects – i.e., reflecting he production changes in both primary effect and indirectly affected sectors.

[1] Technically, emission factors are equivalent to *direct requirements coefficients* within standard input-output analysis terminology.

Although emission factors are calculated using facility-specific data, the TEAM results are aggregated to either counties or states. Presenting the data at the state level mitigates the possible uncertainties associated with the disaggregation process for data that are not originally available at the county level.

2.1 Literature Review

TEAM follows a method that goes back to Ayres and Kneese (1969), Kneese, Ayres and D'arge (1970),and Leontief (1970), and which takes the view that pollution emissions are a fundamental part of production processes, just like raw material inputs, and thus can similarly be treated as an input within an economic Input-Output Analysis framework. This early work was an effort to bring economic analysis more in line with the fundamental law of conservation of mass by showing that pollution "externalities" were intrinsic to economic processes, and not an exceptional case to be addressed through a partial equilibrium analysis of economic welfare (Ayres and Kneese, 1969, p. 283). It is now common practice in environmental economics to treat emissions as an input to production, or as a component of the production function.[2]

TEAM builds on the capabilities of the Environmental Input-Output Model previously developed by Abt associates for the U.S. Environmental Protection Agency (Abt Associates Inc., 2000) to support analysis of greenhouse gas emissions in relation to the structure of the U.S economy.

Alternative approaches exist to develop industry-specific emissions factors linking economic outputs to pollutant emissions and resource use. One approach relies on the evaluation of emissions from a "representative" set of technologies and building engineering-based estimates of emission patterns within in industry.[3] These "bottom up" estimates, however, are subject to the difficulty of defining a "representative" facility, as well as difficulties in linking the parameters from which these technology-based emissions are developed (e.g., fuel consumption) to production quantities and economic values. A second, "top down" approach relies on the use of data on observed emissions, if such data exist, and economic production levels, to estimate emission factors for a given industry and location framework.[4] [5]

TEAM uses this top-down empirical method for developing emission factors, which builds on existing national emissions and resource use inventories. As applied to the development of

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[2] A formal analysis of externalities is available in Baumol, William J., and Wallace E. Oates (1988). The Theory of Environmental Policy, Second edition, New York: Cambridge University Press.

[3] For example, the "Complilation of Air Pollution Emission Factors" (AP-42), a database published and maintained by EPA and available on EPA's Technology Transfer Network Clearinghouse for Inventories & Emission Factors at http://www.epa.gov/ttn/chief/index.html.

[4] For an example of the top-down method, see the IPPS database of pollution intensity coefficients maintained by the World Bank (Hettige et al, 1994).

[5] A comparison of top-down and bottom-up approaches for selected tourism industries can be found in Creason, 2000.

TEAM's emission factors, this empirical approach immediately addresses the issues relative to application of the engineering "bottom up" approach noted above. In particular, the empirical emission factor estimates implicitly reflect the blend of production technologies and specific structure of inputs in relation to output for the given facility or other locational and economic framework being analyzed. In addition, because the empirical method directly relates emissions to the value of economic activity, this method also avoids having to link an engineering -based emission factor to the economic value achieved by that physical activity.

TEAM estimates may be compared to those prepared by the Green Design Initiative at Carnegie Mellon University (Green Design Initiative, 2000).[6] The Economic Input Output Life Cycle Assessment (EIOLCA) software traces out the various economic transactions, resource requirements, and environmental emissions required for a particular product or service. The model captures all the direct and indirect manufacturing, transportation, mining, and related requirements to produce final goods and services. The model is based upon the US Commerce Department's 485 sector input-output model of the US economy.

Emission factors have been used in input-output lifecycle assessments to determine the resource/resource use associated with the production, use and ultimate disposal of consumption items and to compare the "environmental footprint" of various consumption decisions (Hertwich *et al.*, 2003).

Barata (2003) uses solid waste generation rates to study the relationship between economic activities and the generation of solid waste in the Portuguese economy. In this application, the emission factor is expressed in terms of pounds of emission by unit of total output (for manufacturing activities) or per unit of final demand (for household consumption activities).

Beghin *et al*. (1999) follow a slightly different approach to estimating pollution impacts of trade agreement in Chile by estimating pollution effluent intensities by economic sector as a function of energy and input use, rather than from actual inventories. The effluent intensity estimates are based on the Industrial Pollution Projection System database produced by the World Bank and based on U.S. manufacturing and pollution abatement data for 1987, and which are expressed in terms of pollution per employee. The study categorizes the Chilean economy into 75 sectors, each with its pollution effluent intensity. Note that in this case, the emission factor (or "effluent intensity") is expressed in terms of energy/input use (i.e., labor input), which is assumed to be directly related to production and, consequently, to the value of shipments.

## 2.2 Methods

This paper takes emissions/resource use estimates from TEAM and compares them to those published by Carnegie Mellon University (Green Design Initiative, 2000) and to a bottom-up assessment of the environmental effects of tourism industries (EPA, 2000). The analysis is limited to those sectors and resource use categories analyzed in all three studies, that is the hotels, restaurant, and retail sectors; water use, Nox, and CO.

The CMU data were downloaded from www.eiolca.net, THe CMU data is based on the 485 sector BEA model, and sectors were matched as described in the concordance in Table 1. Water use data could be used directly, but the air emissions data were converted from metric tons to tons by dividing by a factor of 1.016.

[6] Available on the internet at http://www.eiolca.net.

## Table 1 Concordances

| IMPLAN | CMU/BEA | TEAM/NAICS |
|---|---|---|
| 479 Hotels and Motels, Including Casino Hotels | Hotels 720101 | Hotels, except Casino 721110<br>CasinoHotels 721120 |
| 481 Food Services and Drinking Places | Eating and Drinking Places 740000 | Food Services and Drinking Places 722000 |
| 401Motor Veh & Parts Dealer<br>402Furniture …stores<br>403Electronics… stores<br>404Building material…stores<br>405Food…stores<br>406Health…stores<br>407Gasoline stations<br>408Clothing…stores<br>409Sporting goods….stores<br>410General merch…stores<br>411Misc store retailers<br>412Nonstore retailers | Retail Trade, ex Eating and Drinking 690200 | Retail Trade 440000-450000 |
| | | |

The EPA tourism study reported emission factors for 12 recreation types for hotels and restaurants. The retail data only covered 9 recreation types. Arithmetic means of the coefficients were taken to produce a single statistic for comparison.

Table 2 shows the emissions/resource use factors for each of the three sources.

## Table 2 Emissions/Resource Use Factors

| | EPA, 2000 (Direct) | CMU Direct | CMU Total | TEAM Direct | TEAM Total |
|---|---|---|---|---|---|
| **Water Use** (Gallons per Dollar) | | | | | |
| Lodging | 2.98 | * | 1.02 | 3.52 | 12.1 |
| Restaurant | 0.64 | * | 2.02 | 30.6 | 50.81 |
| Retail | 0.12 | * | 0.82 | 0.71 | 8.96 |
| | | | | | |
| **Carbon Monoxide** (Tons per millDollar) | | | | | |
| Lodging | 0.14 | 0.02 | 1.52 | 695 | 4,083 |
| Restaurant | 0.02 | 0.27 | 2.68 | 5,870 | 19,725 |
| Retail | 0.02 | 2.28 | 3.33 | 1,683 | 7,244 |
| | | | | | |
| **Nox** | | | | | |
| Lodging | 0.195 | 0.13 | 2.61 | 70 | 834 |
| Restaurant | 0.03 | 0.00 | 3.30 | 559 | 4,118 |
| Retail | 0.02 | 1.28 | 2.88 | 335 | 1,289 |

Notes: Column 1 reports averages across tourism types taken from Table 4 in Creason, 2000

Column 2, 3 reports emission factors from Carnegie Mellon University, 2000

Column 4, 5 report emission factors from the Trade and Environment Assessment Model, EPA 2004.

* CMU report water use for manufacturing sectors only.

## Discussion

TEAM gives emissions estimates that are higher, in every case, than the corresponding estimates from CMU. THis is because of TEAM's wider scope and coverage.

For the water estimates, CMU uses as its data source the Census document Water use in Manufacturing and thus excludes all nonmanufacturing water use. TEAM measures gross withdrawals, consumptive use and instream use from the USGS Aggregate Water-Use Data

System (AWUDS). This data set includes all water users, including domestic, commercial, agricultural, and. Electric utilities. Electric utilities are a particular water user that is excluded by CMU, and accounts for most of the differences reported in Table 3.

For the air emission estimates, CMU relies on EPA's 1996 Aerometric Information Retrieval System (AIRS) database, which again includes only the manufacturing sectors. TEAM instead looks to the 1999 National Emissions Inventory, which includes point source, area source, and mobile sources, and an expanded sector list, including nonroad equipment emissions (for example, farm equipment).[7]

Limitations

As with any economic modeling exercise, the Input-Output framework makes certain simplifying assumptions, which are inherited by TEAM. One particularly strong assumption concerns the use of fixed coefficient production functions. Production in an Input-Output model is homogeneous of degree 1, meaning that increasing output by a factor *N* requires all the inputs to be increased by that same factor. In particular, the marginal product of every input is equal to the average product, and there are no possibilities for factor substitution. In other words, the technology is assumed fixed. This is not a significant difficulty when considering small changes in output and short time horizons, but as impact grow larger and the time to adjust gets longer, these assumptions pose real limitations on the predictive capacity of the model.

Another assumption of the input-output analysis framework is that there are no constraints on inputs or outputs. The model assumes that inputs are supplied without limitations and at a constant price, and that all outputs can be sold at a constant price. Again, these assumptions are reasonable for small changes and short time horizons, which are expected to correspond to the type of scenarios modeled in TEAM.

## B.4 References

Barata, E.J.G. (2002) Solid Waste Generation and Management in Portugal: An Environmental Input-Output Modeling Approach, *7th Biennial Conference of the International Society for Ecological Economics*, Sousse (Tunisia), 6-9 March.

Beghin, J., B. Bowland, S. Dessus, D. Roland-Holst, D. van der Mensbrugghe (1999). Trade,

Environment and Public Health in Chile from an Economy-Wide Model. *Trade, Global Policy and the environment*, The World Bank, Discussion Paper No. 402, pp.35-54.

Creason, Jared R. Analyzing the Envirnmental and Economic Impacts of Tourism. Proceedings of the 2000 IMPLAN Users Conference, Colorado State University, 2000.

Hertwich, E., K. Erlandsen, J. Aasness, K. Sorensen, and K. Hubaceck (2003). Pollution Embodied in Norway's Import and Export and its Relevance for the Environmental Profile of Households. International Institute for Applied Systems Analysis, IIASA Report IR-02-073, pp. 63-72.

[7] The total air emissions from the restaurant sector are particularly driven by indirect effects on agricultural sectors. The entire estimated quantity of CO and Nox from restaurants is from "area sources" such as agriculture, which are not included in the CMU estimate.

Hettige, H., P. Martin, M. Singh, and D. Wheeler (1994). IIPS: The Industrial Pollution Projection system, Policy Research Working Paper #1431.The World Bank.

U.S. EPA (2000). A Quantitative Model for Assessing the Economic and Environmental Impacts of Travel, Toursim, and Recreation in the United States.

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# Costs of Improved Water Quality Standards in the Chesapeake Bay

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An expanded version of this document previously appeared as "Appendix G: Socioeconomic Impacts of the Tier Scenarios in the Chesapeake Bay Watershed" in Economic Analyses of Nutrient and Sediment Reduction Actions to Restore Chesapeake Bay Water Quality *http://www.chesapeakebay.net/ecoanalyses.htm*

1.0 Background

The Chesapeake Bay Program (CBP) is developing revised water quality criteria, designated uses, and boundaries for the bay and its tidal waters, as well as a use attainability analysis (UAA) to support these changes. Among the factors that the CBP is evaluating as part of the UAA is whether the refined designated uses would require pollution controls more stringent than those required under Sections 301(b)(1)(A) and (B) and Section 306 of the Clean Water Act (i.e., nutrient controls) which would result in substantial and widespread social and economic hardship in the Bay watershed. Statutes provide that States may cite substantial and widespread economic impacts of compliance as a reason States may revise the designated uses of a water body.

At the request of EPA's Chesapeake Bay Program (CBP), National Center for Environmental Economics (NCEE) has evaluated the socioeconomic impact of the revised water quality criteria, designated uses, and boundaries for the bay and its tidal waters on the Bay watershed region. Our major objective was to estimate the economic impacts of both the direct and indirect effects of compliance. Measures of economic impacts include changes in the value of regional output, or goods produced, employment, as well as wages and income. These measures are important to determining whether "widespread economic impacts" are present, as defined below and in EPA's Water Quality Standards Handbook (referred to as the "guidance" hereafter).[1]

EPA's guidance specifies three steps to determining whether impacts are expected to be widespread:

? **Step 1:** Define relevant geographic area
? **Step 2:** Estimate socioeconomic changes due to pollution control costs
X **Step 3:** Consider the multiplier effect.

## Geographic Area

The analysis must define the affected community (the geographic area where project costs pass through to the local economy), consider the baseline economic health of the community, and finally evaluate how the proposed project will affect the socioeconomic well-being of the community. Whereas the financial analysis to determine "substantial" impacts is conducted for each affected facility separately, the widespread analysis is conducted for all dischargers jointly (EPA, 1995). Since the Tier scenarios affect dischargers in a multi-state region, analysis of socioeconomic changes cannot ignore that expenditures will occur across this wide area (because

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[1]Interim Economic Guidance for Water Quality Standards: Workbook. Appendix M of Water Quality Standards Handbook. Second Edition. U.S. Environmental Protection Agency. EPA-823-B-95-002. March, 1995.

a cost to one sector is revenue to another sector). Therefore, the relevant geographic area crosses State boundaries.

Estimate Socioeconomic Changes

Estimating the socioeconomic changes that will result from the pollution control costs involves first running a baseline scenario to forecast the conditions that would exist absent the expenditures, and then running a policy scenario to model the impact of the expenditures. The difference in magnitude of socioeconomic indicators such employment, unemployment, income, persons below the poverty line, and tax revenues are the impacts of the controls.

Multiplier Effects

When using economic models to estimate socioeconomic changes, the secondary effects of the control costs are also captured. These secondary effects reflect that each dollar spent in the economy on pollution control results in spending of more than one dollar in the economy (i.e., a multiplicative effect). Similarly, each dollar lost to an employee (i.e., through lost wages) would result in the loss of more than one dollar to the local economy.

## 2.0 Method

NCEE used two models to estimate the socioeconomic impacts of the tier scenarios. First, to obtain a baseline forecast for the six state area, NCEE used a Multi-Region Policy Insight model produced by Regional Economics Models, Inc. (REMI). The REMI model incorporates aspects of computable general equilibrium, input-output, and econometric forecasting models into one model that takes advantage of the relative strengths of each method. The REMI model features:

- ? 53 sectors
- ? 51 regions, including all States plus the District of Columbia
- ? A strong theoretical foundation which has been peer reviewed and demonstrated
- ? Forecasts for a large number of output variables including prices and incomes
- ? Flexibility in analyzing the timing of economic impacts
- ? Ability to accounts for business cycles, reducing error.

Then, NCEE used IMPLAN (Impact Analysis for Planning), produced by the Minnesota Implan Group, Inc.(MIG, 2001), to model the expenditures for pollution control. IMPLAN is an input-output model that, without further calibration, can produce State-level multipliers that are directly comparable to RIMS II multipliers.[2] IMPLAN data are compiled from State, local and national sources including:

- ? U.S. Bureau of Economic Analysis Benchmark I/O Accounts of the United States
- ? U.S. Bureau of Economic Analysis Output Estimates
- ? U.S. Bureau of Economic Analysis REIS Program
- ? U.S. Bureau of Labor Statistics ES202 Program
- ? U.S. Bureau of Labor Statistics Consumer Expenditure Survey
- ? U.S. Census Bureau County Business Patterns

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[2]The REMI and IMPLAN frameworks provide a more credible and theoretically sound basis for estimating socioeconomic impacts compared to the simple use of multipliers. In multiplier analysis, care must be taken to model both the cost and revenue impacts that will result from controls.

- ? U.S. Census Bureau Decennial Census and Population Surveys
- ? U.S. Census Bureau Economic Censuses and Surveys
- ? U.S. Department of Agriculture
- ? U.S. Geological Survey.

The IMPLAN model features:

- ? 528 Industrial Sectors, typically at the 4-digit Standard Industrial Classification level in manufacturing, 2–3 digit for other sectors
- ? All states and counties in the United States
- ? All elements balanced to the National Income and Product Accounts
- ? Conformity to I/O accounting definitions
- ? Modeling flexibility.

The Implan system produces impact estimates measured in changes from the base year, assuming no other changes in the economy. In other words, the Tier scenario impacts are estimated assuming the costs and spending took place, but the underlying structure of the economy remained the same. Thus, the Tier scenario impacts do not incorporate the changes in the baseline forecast.

## 3.0 Baseline Forecast

**Exhibit G-2** provides the highlights of the baseline forecast for the State of Maryland, which is located entirely in the Chesapeake Bay watershed, through 2010. The first column lists the values for the year 2000.

The REMI model forecasts that the Maryland economy will grow through 2020. In 2010, gross regional product (GRP) is projected to be 37.1% higher than in 2000. Employment will also grow. In 2010, Maryland will have 18.6% more workers than in 2000. Compared to the rest of the United States, the exhibit shows that in 2000 Maryland employed 1.8% of the nations workers, and by 2010, this percentage is expected to grow by 9.5% (i.e., in 2010, MD will have 2.0% of the Nation's workers). Population, at 5.2 million in 2000, will grow by 15% by 2010. People will be better off, as shown by real disposable personal income (RDPI), which is forecast to expand by 17.1% by 2010.

Exhibit G-1: Macroeconomic Forecast, 2000–2020, Maryland

(percent growth over year 2000 values)

| Factor | 2000 | 2005 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|
| GRP (Billions 1992 $) | 158 | 187(18.6) | 217(37.1) | 243(53.7) | 268(69.5) |
| Employment (Thousands) | 3,106 | 3445(10.9) | 3,863 (18.6) | 3,818(23.0) | 3,932(26.6) |
| – Percent of U.S. | 1.8 % | 1.9(5.6) | 2.0(9.5) | 2.0(10.1) | 2.0(10.6) |
| Population (Thousands) | 5,238 | 5,599(6.8) | 6,051(15.5) | 6,441(23.0) | 6,780(29.4) |
| RDPI per cap (Thousands 1992 $) | 23.4 | 25.6(9.2) | 27.5(17.1) | 28.8(22.7) | 30.2(28.7) |
| Manufacturing Employment (Thousands) | 187.7 | 183.2(–2.4) | 180.9(–3.6) | 184.0(-2.0) | 187.8(0.0) |
| Non-Manufacturing Employment (Thousands) | 2,374.8 | 2,674.4(12.6) | 2,882.1(21.5) | 2,991.3(26.0) | 3,087(30.0) |
| Farm Employment (Thousands) | 17.9 | 16.2(-9.8) | 14.8(-17.5) | 14.1(–21.5) | 13.4(–25.4) |

The economy in the future will continue to evolve. The last three rows of Exhibit G-2 show employment in various sectors. Manufacturing and farm employment will decrease by 3.6 and 17.5% respectively, while non-manufacturing will continue to expand by 21.5% by the year 2010. Also, by 2020, most of manufacturing jobs have returned, but farm jobs continue to disappear.

## 4.0Impact of Tier Scenarios

To estimate the impact of the tier scenarios on the baseline conditions described above, the draft tier cost estimates are modeled using IMPLAN.

### Distribution of Program Costs and Spending

Exhibit G2 shows annual costs and spending patterns resulting from the Tier 3 scenario.[3] These data appear different from those presented in other sections because these data are presented by payer or payee rather than by sector. For example, Households are assumed to pay for POTW improvements as well as urban & mixed open nonpoint programs, state funded portions of agricultural cost sharing, and septic system improvements. Similarly, the water supply and sewerage systems sector is assumed to receive money spent for POTW improvements as well as

[3]Tier 1 and 2 show similar patterns, but with lower totals.

urban and mixed open nonpoint controls and industrial sector upgrades. This table, in reducing some of the sector -level data to simple "payer" and "payee" groups, illustrates some of the important distributional effects of the Tier 3 scenario.

The total spending amount of $1,139.291 million exceeds the cost total of $948.720 million by over $190 million dollars, representing the flow of federal dollars into the region as a result of Tier 3 scenario. While in reality, the taxpayers of the region would pay some of this cost through federal taxes, the Federal government has a much larger population and more flexibility in budgeting than the states have. We assume that, for purposes of this analysis, the federal budget is exogenous.

Exhibit G2 shows that Households (i.e. the public) are the largest paying sector, with $805.7 million in expenditures in 2010 under Tier 3 for POTW improvements as well as urban & mixed open nonpoint programs. Agriculture and Forestry (private) sectors combined face $127.663 million in costs, and the industrial sectors combined face $15.347 million in costs. Water supply and sewerage systems is te largest payee sector, receiving $712.442 million in spending for POTW improvements, urban & mixed open nonpoint programs, and industrial improvements. The Agricultural services receives $407.823 million for agricultural and forest BMPs, and Residential Maintenance and Repair sector receives $13.026 million for septic system improvements.

Exhibit G2. Incidence of Costs and Distribution of Tier 3 Spending

| Costs ("Payers") | State | Amount (millions) | Spending ("Payees") | State | Amount (millions) |
|---|---|---|---|---|---|
| Households | DE | 5.694 | Water Supply and Sewerage | DE | 3.174 |
| | DC | 34.091 | | DC | 34.058 |
| | MD | 223.163 | | MD | 207.431 |
| | NY | 39.398 | | NY | 31.766 |
| | PA | 187.087 | | PA | 151.789 |
| | VA | 301.208 | | VA | 279.681 |
| | WV | 15.069 | | WV | 10.543 |
| | Subtotal: Households | 805.710 | | Subtotal Water Supply & | 718.442 |
| Agriculture & Forestry | DE | 2.159 | Agricultural Services | DE | 10.251 |
| | DC | 0 | | DC | 0 |
| | MD | 4.262 | | MD | 51.599 |
| | NY | 12.504 | | NY | 32.817 |
| | PA | 53.529 | | PA | 163.931 |
| | VA | 43.680 | | VA | 123.388 |
| | WV | 11.529 | | WV | 25.837 |
| | Subtotal: Ag & Forestry | 127.663 | | Subtotal Ag Svc Services sc | 407.823 |
| Industry | DE | 0 | Residential Repair | DE | 0.181 |
| | DC | 0 | | DC | 0.033 |
| | MD | 2.676 | | MD | 3.251 |
| | NY | 0 | | NY | 1.132 |
| | PA | 4.136 | | PA | 4.106 |
| | VA | 7.924 | | VA | 3.944 |
| | WV | 0.611 | | WV | 0.379 |
| | Subtotal: Industry Industry | 15.347 | | Subtotal Residental Repair: | 13.026 |
| Totals | | 948.720 | | | 1,139.291 |

Household costs include POTW improvements, urban & mixed open nonpoint programs, state funded portions of agricultural cost sharing, and septic system improvements. Agriculture,Forestry, and Industry costs include only the private costs for those sectors. Water Supply and Sewerage receives payments for POTW improvements, urban & mixed open nonpoint programs, and industrial improvements. Agricultural Services receives payments for

Ag andForestry improvements. Residential Repair sector receives payments for septic improvements.

The Impact analysis discussed below takes the costs and spending in Exhibit G2 and adds the indirect and induced (or "ripple") effects to estimate total impacts. As one might expect, the fact that spending exceeds costs is translated into net positive impacts for all three tiers. Moreover, in terms of macroeconomic variables such as employment and economic output that are important in determining widespread impacts, there is a slight gain in transferring dollars from consumers who largely purchase goods imported to the region, to local infrastructure development. This is all detailed in the sections that follow.

## Impact Analysis

### 4.1 Modeling Assumptions

To model the pollution control expenditures, the costs are translated into changes in economic variables.

### POTWs

The POTW sector will face increased cost of treatment, in the form of capital and O&M expenditures. Some of these costs are paid by State and Federal funds. Based on the assumptions developed by the UAA workgroup and presented elsewhere in this document, capital cost shares of 50% are expected in MD and 10% in VA; facilities in all other States pay capital cost in entirety. In MD, this cost share is modeled in IMPLAN as 25% from State sources and 25% from Federal sources. However, due to the timing of the change in the assumption for VA, the results below reflect a 50% costs share for that state similar to that for MD.

For the State and POTW sector, NCEE assumed revenue neutrality, and modeled the costs as being passed on to residential customers through higher fees. This is accomplished by decreasing household consumption equal to the annual O&M expense plus 75% of the annualized capital cost (since 25% of the capital cost is paid by Federal sources). In other States and the District of Columbia, household consumption is decreased by the O&M cost plus 100% of the annualized capital cost.

On the revenue side, the economic impact of expanding POTWs is modeled by increasing output of the water supply and sewerage systems sector by the full amount of annual O&M expenditures plus 100% of the annualized capital cost.

### Industrial Facilities

Certain industries face increased cost of treatment under the various tiers. NCEE modeled these costs as a decrease in output. This implicitly assumes that these firms sell undifferentiated into a competitive national or world market, which seems reasonable considering the industries represented. This also is a conservative approach. If on the other hand, firms hold a regional monopoly, the costs would come out of profits, not output, and employment effects would be minimal.

Water pollution abatement control in the affected industries consists mainly of procedures to remove BOD and toxics, not unlike the processes used by a sewage treatment plant. Therefore, the revenues generated from expenditures on controls fall to the sewage treatment sector input suppliers.

Agriculture

Agriculture will be responsible for a large portion of the control costs. However, the sector will receive a great deal of cost sharing from State and Federal sources. Based on an analysis of the most recent legislative provisions, the distribution of public funds is approximately 68% Federal, and 32% State. For the State, NCEE assumed revenue neutrality, meaning that costs are passed on to residential customers through higher taxes, and modeled the impact of increased taxes as a decrease in household consumption equal to the State portion of costs. Private sector (on-farm) costs are modeled as a decrease output of food grains.

The revenue impact of expanding agricultural BMPs is modeled by increasing output of agricultural services sector by the full costs, including State and Federal portions.

Forestry

The impact of forestry control costs is modeled by decreasing output in the forestry sector, and increasing revenues to the agricultural and forestry services sector.

Urban

NCEE modeled urban and mixed open land use control costs similar to POTWs, but without cost sharing. Costs are assumed to be passed on to residents through higher fees (revenue neutrality), who compensate by reducing household expenditures. The expenditures boost the output of the water supply and sewerage systems sector.

Septic Systems

Many aging septic systems will be upgraded under Tiers 2 and 3, and NCEE modeled the impact of these expenditures as a decrease in other household expenditures, and in increase in demand for the residential maintenance and repair (skilled labor category including plumbers and licensed contractors).

4.2 Results

**Exhibit G-3** lists the IMPLAN model results for each state and tier. The impact results are measured in terms of output, employment and value added.

- **?** ***Output*** means the dollar value of all goods and services produced in the state. Negative (positive) numbers mean reductions (increases) in output, that is declining (increasing) gross regional product.
- ? ***Employment*** is the total effect on statewide employment, counting all direct and ripple effects.
- ? ***Value Added*** includes labor income, corporate income and indirect business taxes.

The rows in **Exhibit G-3** represents the sectors affected by specific control measures and are discussed below. The column labeled “TierIII Costs” represents the direct and “ripple” effects of the nutrient and sediment reduction actions. For example, the total jobs figures under the Economic Impact sub-heading in the Tier III Cost column represents the economy-wide employment impact in all sectors.

The column labeled Tier III Spending shows the stimulus effect of program--related spending to implement the nutrient and sediment reduction actions. For example, the total jobs figure under the Economic Impact subheading in the Tier III Spending column represents the number of additional jobs supported. In most instances, this number exceeds the number of jobs lost. However, a couple of caveats apply: First, the model assumes no supply constraints for labor or materials. These total impacts can only be realized if there are, in fact, workers available to take the positions and no other resource constraints are binding. The second caveat is that this is the long-term effect, and some time will be required before the spending impacts are fully realized.

The socioeconomic impacts are modest on net, but there are important distributional consequences. Overall, consumers bear most of the costs through higher taxes (for Agricultural controls) or higher water and sewer fees, or both. Reductions in disposable income tend to concentrate cost impacts on the retail, restaurant, and service sectors. Spending impacts occur in many skilled professional and technical areas such as water treatment, construction, agricultural services. It also should be emphasized that because of the small size of these impacts relative to the sectors themselves, the true implications of these impacts are higher or lower growth, not absolute expansion or contraction.

## 4.3 Summary

Given the size of the regional economy ($1.4 trillion in personal income in 1999 in the six-State area and the District of Columbia, including $573 billion in Bay counties), impacts over this area are likely to be modest. For example, gross regional product in the State of Maryland is forecast to grow by 37% by 2010, corresponding to 19% growth in employment and 17% growth in real disposable personal income (REMI, 2002). The Minnesota Implan Group's (2001) economic impact model indicates that the Tier 3 scenario would result in a net increase in output and employment over this baseline level of growth. The increased economic benefits result from increased spending in high wage industries (e.g., wastewater treatment) as well as an influx of funds for pollution controls (e.g., Federal cost shares for agricultural best management practices); not included are additional market benefits likely to result from improved water quality (e.g., commercial and recreational fishing industries). Therefore, the regional economy is forecast to be stimulated by the Tier scenarios.

The estimated annual cost of Tier 3 for 2010 populations ($1.2 billion in 2001 dollars) represents 0.2% of personal income in the Bay counties in 1999. Even if all capital costs ($7.6 billion) for this scenario were incurred in one year, they represent only 1.3% of personal income in the Bay counties in 1999. Although these data indicate that the pollution controls specified in the Tier scenarios will not result in substantial and widespread social and economic hardship, there may be localized areas that need funding priority; variances can also be used, under certain circumstances, at the local level.

Exhibit G- 3: Economic Impact, Tier III

| Source Category | Tier III Costs | | Tier 1 Spending | |
|---|---|---|---|---|
| | Economic Effect | Economic Impact | Economic Effect | Economic Impact |
| Agriculture – private | Reduced Output<br>$96,727,038 | TIO...………($158,055,420)<br>Total Jobs..................(3,281)<br>Value Added...($59,014,926) | Increased Output:<br>Ag. Services<br>$376,281,290 | TIO ........$467,980,737<br>Total Jobs.…….........10,067<br>Value Added....$138,927,131 |
| Agriculture – public | Reduced Household Consumption<br>$89,589,762 | TIO...……....($128,659,898)<br>Total Jobs.................(1059.8)<br>Value Added...($69,864,748) | | |
| Urban & Mixed Open | Reduced Household Consumption<br>$417,568,560 | TIO……......($581,445,045)<br>Total Jobs.................(6348.2)<br>Value Added.($299,443,237) | Increase Output: Water Supply & Sewerage<br>$417,568,560 | TIO...........$657,506,693<br>Total Jobs......................5891<br>Value Added....$419,291,823 |
| Septic | Reduced Household Consumption<br>$13,026,369 | TIO...………...($18472791)<br>Total Jobs..................(211.4)<br>Value Added.......($9900108) | Increase Output: Residential Maintenance and Repair<br>$13,026,369 | TIO……….......$21,884,059<br>Total Jobs......................274<br>Value Added.....$10,802,485 |
| POTW | Reduced Household Consumption<br>$285,526,139 | TIO...…......($344,081,110)<br>Total Jobs...................(4172)<br>Value Added.($200,420,500) | Increase Output: Water Supply & Sewerage<br>$285,526,139 | TIO...……........$450,561,179<br>Total Jobs......................3,976<br>Value Added....$287,434,169 |
| Industrial | Reduced Output<br>$12,671,555 | TIO……......($21,948,293)<br>Total Jobs.....................(151)<br>Value Added.......($7247183) | Increase Output: Water Supply & Sewerage<br>$12,671,555 | TIO...………......$19,829,628<br>Total Jobs.....................189<br>Value Added......$12,542,462 |
| Forest | Reduced Output<br>$30,754,731 | TIO...….......($44,512,946)<br>Total Jobs.....................(573)<br>Value Added...($17,808,192) | Increase Output:<br>Ag. Services<br>$30,754,731 | TIO.............$38,897,639<br>Total Jobs ...…...............791<br>Value Added.....$12,198,441 |
| Total | Cost<br>$945,864,154 | TIO……...($1,297,175,503)<br>Total Jobs................(16,246)<br>Value Added($663,698,894) | Spending<br>$1,135,828,644 | TIO……...$1,656,659,935<br>Total Jobs ................21,186<br>Value Added...$881,196,511 |

# Direct, Indirect, and Induced Impacts from Co-Firing Biomass Feedstocks in Southeastern United States Coal-Fired Plants

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## Background

Electricity from coal-firing provides over 50 percent of the electricity generated in the United States. For the Southeast United States, 60 percent of the electricity demand depends on coal (Department of Energy, 2001b). Although coal-fired plants are important sources of electricity in the United States, negative environmental impacts are associated with this type of electricity generation. About two-thirds of sulfur dioxide ($SO_2$), one-third of carbon dioxide ($CO_2$), and one-fourth of nitrogen oxide ($NO_x$) emissions are produced by burning coal. Particulate matter is also emitted when coal is converted to electricity. The Southeastern Region of the U.S. leads in $CO_2$ emissions and ranks second in emissions of $SO_2$ and $NO_2$ (Department of Energy, 1999).

When compared with coal, biomass feedstocks (agriculture residues, dedicated energy crops, forest residues, urban wood waste, and wood mill wastes) have lower emission levels of sulfur or sulfur compounds and can potentially reduce nitrogen oxide emissions. In a system where biomass crops are raised for the purposes of energy production, the system is considered carbon neutral since crops absorb carbon during their growth process. Thus, the net emissions of the $CO_2$ are much lower compared with coal-firing (Haq).

The credits for offsetting $SO_x$ emissions, currently priced at $100 per ton, provide an incentive for co-firing biomass with coal (Comer, Gray, and Packney). Costs of conversion of power plants for co-firing are relatively modest at the lower levels of percent biomass in the mix. Power companies also have the potential in the future to obtain marketable value through offsetting $CO_2$ for greenhouse gas mitigation. Replacing coal with biomass offers a means for achieving $CO_2$ reductions while maintaining operational coal generating capacity (Comer, Gray, and Packney). Co-firing, as compared with 100 percent biomass use, is not reliant on a continuous supply of biomass because of a ready supply of coal (Demirbas).

This study examines the economic impacts of co-firing biomass feedstocks (forest residues, primary mill residues, agricultural residues, dedicated energy crops-switchgrass, and urban wood wastes) with coal in coal-fired plants in the Southeastern United States. The impacts of using each type of feedstock are evaluated for three emission credit and two co-firing level scenarios. The potential economic impacts (total industry output, employment, value added) for producing/collecting/transporting the feedstock, retrofitting the coal-fired utilities for burning the feedstock, operating co-fired utilities, and the coal displaced from burning the feedstock are estimated.

## Methodology

The power plants studied for this analysis were associated with the Southeastern Electric Reliability Council **(**SERC), the regional organization for the coordination of the operation and planning of the bulk power electric systems in the southeastern United States. This region includes areas in eight states – Alabama, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. Power plants in each of these states were identified and incorporated into the analysis. In order to conduct the regional economic impact analysis, trading regions within the eight states were identified. These regions were based on the Bureau of Economic Analysis Trading Areas (referred as Economic Trading Areas (ETA) in this study).

The analysis uses the Oak Ridge County-Level Biomass Supply Database (ORCBS) and three additional models – Oak Ridge Integrated Bioenergy Analysis System (ORIBAS), Oak Ridge Competitive Electricity Dispatch (ORCED), and Impact Analysis for Planning (IMPLAN). The ORCBS Database provides county biomass quantities available at several price levels for multiple feedstock categories (forest, agricultural, and mill residues; dedicated energy crops; urban wood wastes) and sub-categories (e.g., spring and winter wheat straw; corn stover for agricultural residues) for the United States. The Oak Ridge Integrated Bioenergy Analysis System is a GIS-based transportation model used to estimate the delivered costs of biomass to power plant facilities (Graham et al., Noon et al.). The Oak Ridge Competitive Electricity Dispatch model is a dynamic electricity distribution model that estimates the price utilities can pay for biomass feedstocks. ORCED models the electrical system for a region by matching the supplies and demands for two seasons of a single year. The IMPLAN model uses input-output analysis to derive estimated economic impacts for constructing and operating the power plants, the transporting of the bio-based feedstocks, and the growing/collecting of wastes, residues, and dedicated crops in the eight states.

For each power generating location, ORIBAS provides the delivered cost of the bio-based feedstock, the cost of transporting the feedstock from collection point to the demand center, the value paid to the original owner of the feedstock, and the location of the feedstock and the power plant.

The delivered value that the power facilities are willing to pay per MMBtu is estimated by ORCED and that information is supplied to ORIBAS. Once ORIBAS is solved, the number of plants that can get sufficient quantities of biomass delivered at the pre-specified price is estimated along with the location, quantity, and value of the biomass supplies. This information is then converted into direct economic impact estimates and used by IMPLAN.
Impacts are estimated for four economic sectors. A one-time only impact in the construction sector is estimated. Annual impacts are estimated for electrical generation, growing/collecting of the bio-based feedstock, and transportation sectors. In addition, the difference between the amount the power plant is assumed to pay for the residue and the cost of growing/collecting that residue is estimated. This amount is assumed to go to the original owner of the feedstock as a change in proprietary income. In areas that produce coal that is being replaced by residue within the Southeast, a negative impact from the reduction of coal mining is estimated.

### *Co-firing Scenarios Analyzed*

Two levels of co-firing are examined in the analysis – 2 percent or 15 percent (by weight) of the coal replaced by bio-based feedstocks. In addition, three levels of carbon taxes are assumed – $0 (Base), $70 (Low Carbon), and $120 (High Carbon) per ton of pollutant emitted. Further, each ton of $SO_x$ produced has a negative value of $142. In the positive carbon tax scenarios, each ton of $NO_x$ pollutant generates -$2,374 (Department of Energy, 2001a). This results in a total of five scenarios to be estimated – Base Case 2%, Low Carbon 2%, Low Carbon 15%, High Carbon 2%, and High-Carbon 15%.

### *Total Project Investment (Plant Construction)*

The costs of converting power plants to co-firing differed depending on whether a 2- or 15-percent co-fire was assumed. If a 2 percent co-fire is assumed, the costs of conversion are estimated to equal $50/kw (Van Dyke). Likewise, for the 15% co-fire scenario, the investment cost was estimated to be $200/kw (Van Dyke). Each power plant was rated with a plant capacity and a capacity factor (Van Dyke).

Based on information provided by Van Dyke, a million dollar investment was proportioned through the economy and assigned to the appropriate IMPLAN industry sectors. Each ETA was then impacted with a million dollar investment for both the 2% and 15% co-firing scenarios. The impact of this million dollar investment was then divided by the direct impact to develop a multiplier ($MULT_{ETA,m}$ where ETA is a prespecified trading area and m is the percent co-fire assumed).

To determine the impact of the investment stage within an ETA, the total investment required for all power plants within the ETA expressed in millions of dollars was multiplied by the multipliers for TIO, employment, and value added. This can be represented as:

$$IMPACT_{ETA,m} = MULT_{ETA,m} * \sum_{p=1}^{n} INVEST_{p,m}$$

where p is the number of plants in the ETA.

### ***Annual Operating Costs***

The IMPLAN sector representing electricity production was modified to reflect an increase in annual machinery repair expenditures. Employment compensation was increased to reflect the additional labor requirements. Assuming a $1 million change, employment compensation was increased by $750,000 and machinery by $250,000 (Van Dyke). Using IMPLAN results, operating multipliers were estimated for total industry output, number of jobs, and value-added (Olson and Lindall). To estimate the increased amount spent per year to operate the power plant, the amount of coal replaced by biomass was multiplied by 22, the amount of mmBtu's in coal, and then by $0.09. The $0.09 is the estimated operating cost per mmBtu (Van Dyke). The total impact on the economy in terms of output, jobs, and value-added is estimated by multiplying the amount spent per year with the appropriate multiplier.

### *Bio-based Feedstock Costs*

Each of the six types of bio-based feedstocks considered in the analysis had a different cost structure. These distributions were then multiplied times a million dollars and assigned the appropriate IMPLAN sector. The non-labor costs were used to adjust the current production function of the sector most likely to provide the output.

A new economic impact model was created for each bio-based feedstock with adjusted production function coefficients reflecting the new activity in the economy. Total industry output, employment, and value-added multipliers were then generated for each bio-based feedstock. These multipliers were multiplied by the cost of producing/collecting the feedstock that ORIBAS indicated would be used by the power plant. The economic impact that co-firing would have in the areas where the feedstock originated was then estimated.

### *Proprietary Income Impacts*

The value paid for the bio-based feedstock determined by ORIBAS for each scenario was subtracted from the per acre cost to estimate impacts on proprietary income. An impact analysis on proprietary income was conducted in each ETA and the multiplier generated multiplied by the total change in proprietary income served as an estimate of the impacts that would occur as a result of an increase in profit within the region.

### ***Transportation Sector Impacts***

Total transportation sector impacts were determined by summing costs of the biomass transported to the power generating facility over all trips and residue types. The result was a change in total industry output. Input-output multipliers for the ETA's in which the power plants are located were then used to estimate the impact on the economy, employment, and value-added.

## Results

### ***Consumption of Residues by Scenario***

In each of the scenarios evaluated some residues were projected to replace coal as a fuel. Under the Base Case, a 2% co-fire scenario generates a demand of 0.51 million metric tons of residue. The residue demanded consists of mill and urban wastes, plus forest residue. Agricultural residues or dedicated crops cannot compete with coal prices, and therefore, are not demanded. In the Base Case, feedstock owners are projected to receive slightly over $16/ton for urban waste to nearly $21/ton for forest residue. At these prices, no dedicated crop or agricultural residues are purchased by the power plants. Over 510,000 metric tons of residues are used producing 8.4 trillion Btu's. Using a conversion factor of 293 kilowatt hours per million Btu's, and an energy conversion efficiency of one third from fuel to electricity out, an estimated 817.6 Gwh of electricity is produced. Demand for residue occurs in seven of the eight states with concentrations near urban areas and near power generating facilities.

In the other four scenarios, as percent co-fire increases so does the amount of residue demanded, and as the amount the utility is willing to pay for residue increases the demand for residues increases. However, this increase is not uniform among all units as competition among units for placing electricity on the grid changes as the cost of generating electricity changes. Indeed, as the system moves from a low carbon to a high carbon tax, less total residue is demanded in the 2% co-fire solution. In the High Carbon 15% co-fire scenario, 29 million metric dry tons of biomass is used in the generation of 45,685 Gwh of electricity.

In both the 2- and 15-percent co-fire solutions, dedicated crops play a large role in the mix of residues, wastes, and dedicated crops. Nearly 40 percent of the bio-based feedstock used in the co-fire comes from dedicated crops in both co-fire solutions. Dedicated crops increase from a low of 0 tons of use in the Base to 1.6 million metric dry tons in the 2% co-fire scenario and 11.0 million metric dry tons in the 15% co-fire scenario. Total biomass use increases to 4 million metric dry tons in the 2 percent co-fire scenarios and 22 and 29 million dry tons in the low and high carbon, 15% co-fire scenarios, respectively. Geographic locations producing the bio-based feedstocks expand as the amount of bio-based feedstock produced increases.

The value of the residues to the power plant increases as the value of coal decreases. In the Base Case, the price paid by power plants average $23-$24 per ton. In the High Carbon 15% scenario, this value increases to $55 per ton with the "farm gate" price ranging from a low of $18.40 for urban waste to $45.75 for some of the agricultural residues.

### *IMPACTS TO THE COAL INDUSTRY*

Using biomass instead of coal to generate electricity will result in a decrease in coal demand within the region. The amount of decrease depends on the amount of coal that would have been purchased within the region had the substitution of bio-based feedstocks not occurred. This study estimated the amount of decrease by the BEA study regions based on state proportion of coal purchases estimated to be replaced.

In the Base solution, 355 thousand tons of coal is replaced by biomass. A decrease of 3,344 tons of sulfur emissions along with a decline of $8.4 million dollars in coal purchases within the region is estimated. This decrease in coal purchases reduces economic activity within the region by $15.5 million dollars and 127 jobs are reduced as a result of the decreased purchases (Table 1). These impacts increase as demand for coal declines.

### *TOTAL IMPACTS RESULTING FROM CO-FIRING BIO-RESIDUES*

The bio-based feedstock sectors gain $10.3 million annually (forest residues—$0.6 million, mill waste—$4.2 million, and urban waste—$5.5 million) for producing, harvesting, and collecting the feedstock. In addition, $1.4 million is paid toward the transportation of the feedstock to the power generating facilities (Table 1). An estimated $0.7 million in operating costs occur annually with an additional $4.6 million in investment required to convert the exclusive coal burning system to co-fire. Proprietors' income within the region is estimated to increase in excess of $1.3 million as a result of coal replacement with biomass.

Incorporating the decrease in coal demand that would occur with the substitution of biomass of $8.4 million, the region's annual increase in direct economic activity in the Base Case, 2% Co-fire scenario is estimated at $5.5 million and nearly 64 additional jobs. The direct, indirect, and induced impacts yield a total impact of $7.4 million annually with an additional one time impact of $7.5 million as a result of increased investment for converting the facilities into co-fire units. An estimated 100 additional jobs are created annually with an additional 68 jobs created as a result of investment.

In the 2% co-fire scenarios, as the Carbon Tax increases, economic activity first increases and then slightly declines. A comparison of the Base with the Low Carbon scenarios shows total economic activity impacts as measured by total industry output increases from $7.3 million to $260.5 million. This occurs despite a decrease in economic activity as a result of replacing coal of $110 million. An additional $6.5 million is spent operating the power plants and $14.6 million is spent transporting the bio-based feedstocks. These impacts increase total economic activity by $9.2 and $29.9 million for operation and transportation sectors, respectively. Job increases within the region are projected to exceed 3,800 in both the low and high carbon 2% scenarios.

The Baseline 15% co-fire scenario was not economically feasible. In the Low Carbon scenario, nearly $1 billion is spent on the production, harvest, and/or collection of the bio-based feedstocks. This amount increases to nearly $1.6 billion under the high carbon tax situation. Adding the indirect and induced impacts to the direct impacts resulted in an estimated $1.5 and $2.4 billion annual total industry output impact to the region's economy. An additional impact of $430 million and $533 million occurs as a result of increased transportation of bio-based feedstocks in the Low Carbon and High Carbon tax scenarios, respectively. Operating costs in the power facility increases $36 to $47 million. With the added impacts that occur as a result of these expenditures, an estimated increase in the economy of $52 and $68 million is projected for the Low Carbon and High Carbon tax scenarios, respectively. Finally, for both the Low Carbon and High Carbon tax scenarios, less coal is purchased from the region and this decrease in economic activity resulted in an estimated $600 or $800 million reduction, respectively.

The number of jobs within the region will increase overall. A decrease in jobs caused by a decrease in coal demand (-6,500 in the High Carbon, 15% Co-fire solution) is offset by the increase in employment of 6,000 as a result of changes in the transportation industry, 500 jobs in the power industry, and 32,000 jobs in the supply of biomass industries. Impacts are similar for all the co-fire scenarios.

## Conclusions

Co-firing does appear economically competitive under the current market conditions with low co-fire levels. Very small amounts of residue (2%) are economically feasible for co-fire in the Base Case. However, assuming a 15% co-fire, the analysis indicates paying the sulfur emissions cost is more economical than burning residue. The analysis does indicate that there are areas that would benefit from generating electricity using forest residues, mill waste, and urban waste. In fact, nearly 817 Gwh of electricity could be produced using these residues replacing 355,000 tons of coal.

Increases in percent co-fire from 2 to 15% resulted in a reduction of additional residue demand in the Base Case. In both the Low Carbon and High Carbon emissions cost scenarios, the amount of residues consumed will significantly increase from 4 million metric dry tons to 23 (Low Carbon) and 29 (High Carbon) million metric dry tons (Table 1). This expansion in residue demand resulted in significant increases in regional economic impacts. There is an estimated $1.4 to $2.2 billion dollar impact that occurs to the Southeast Region under the high co-fire levels with Low Carbon and High Carbon emission cost scenarios, respectively. Concurrent with this increase in economic activity is an estimated increase of 25,000 jobs.

No attempts are made to evaluate the overall U.S. impacts nor is the impact of increased feedstock costs as a result of the employment of environmental taxes incorporated into the analysis. Furthermore, the authors recognize that additional economic impacts that are not captured would occur to the rail industry (transportation of coal) and other forward linked sectors to the coal industry. Finally, estimation of the long-term economic benefits accruing to the region as a result of a cleaner environment is beyond the scope of this study.

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Table 1. Estimated Total Impact on the Economy as a Result of Increased Demand for Bio-Based Feedstocks using Total

**Industry Output, Employment, and Total Value-Added Indicators by Carbon Tax and Co-fire Percent Scenario**

| Estimated TIO Impacts | Base Case 2% | | Low Carbon 2% | | Low Carbon 15% | | High Carbon 2% | | High Carbon 15% | |
|---|---|---|---|---|---|---|---|---|---|---|
| $1,000 dollars | Direct | Total | Direct | Total | Direct | Total | Direct | Total | Direct | Total |
| Transportation | $1,455 | $2,995 | $14,569 | $29,862 | $215,291 | $432,973 | $13,431 | $27,559 | $257,456 | $533,618 |
| Operating | $704 | $1,011 | $6,437 | $9,231 | $36,034 | $51,556 | $6,437 | $9,231 | $47,495 | $68,154 |
| Coal Replacement | -$8,368 | -$15,512 | -$60,117 | -$110,063 | -$325,295 | -$596,173 | -$60,117 | -$110,063 | -$439,634 | -$805,137 |
| Bio-based Feedstocks | $11,663 | $18,854 | $218,340 | $331,425 | $975,436 | $1,516,413 | $217,815 | $330,239 | $1,594,662 | $2,458,748 |
| Total Annual Impact | $5,453 | $7,349 | $179,229 | $260,455 | $901,465 | $1,404,770 | $177,566 | $256,967 | $1,459,979 | $2,255,383 |
| Investment (Non-annual) | $4,655 | $7,577 | $43,533 | $71,204 | $1,080,693 | $1,830,102 | $43,533 | $71,204 | $1,382,542 | $2,367,249 |
| Estimated Job Impacts | | | | | | | | | | |
| | Base Case 2% | | Low Carbon 2% | | Low Carbon 15% | | High Carbon 2% | | High Carbon 15% | |
| (Number created) | Direct | Total | Direct | Total | Direct | Total | Direct | Total | Direct | Total |
| Transportation | 14.3 | 34.9 | 142.8 | 342.1 | 2,120.5 | 5,042.9 | 131.6 | 315.7 | 2,520.8 | 6,095.9 |
| Operating | 3.6 | 8.0 | 33.0 | 71.7 | 187.0 | 407.4 | 33.0 | 71.7 | 243.8 | 530.5 |
| Coal Replacement | -34.4 | -126.9 | -249.4 | -899.6 | -1,348.3 | -4,881.9 | -249.4 | -899.6 | -1,823.0 | -6,586.5 |
| Bio-based Feedstocks | 79.8 | 180.8 | 2,771.6 | 4,368.1 | 12,540.5 | 20,195.4 | 2,774.5 | 4,368.9 | 20,309.2 | 32,570.6 |
| Total Annual Jobs | 63.3 | 96.8 | 2,698.0 | 3,882.3 | 13,499.7 | 20,763.8 | 2,689.7 | 3,856.7 | 21,250.8 | 32,610.5 |
| Investment (Non-annual) | 29.8 | 67.8 | 275.0 | 631.0 | 8,720.9 | 19,210.4 | 275.0 | 631.0 | 11,057.8 | 24,559.1 |
| Estimated Total Value Added Impacts | | | | | | | | | | |
| | Base Case 2% | | Low Carbon 2% | | Low Carbon 15% | | High Carbon 2% | | High Carbon 15% | |
| $1,000 dollars | Direct | Total | Direct | Total | Direct | Total | Direct | Total | Direct | Total |
| Transportation | $605 | $1,514 | $6,066 | $15,042 | $89,170 | $216,183 | $5,595 | $13,886 | $107,336 | $269,693 |
| Operating | $277 | $467 | $2,538 | $4,237 | $14,185 | $23,632 | $2,538 | $4,237 | $18,722 | $31,298 |
| Coal Replacement | -$3,741 | -$7,980 | -$26,689 | -$56,193 | -$144,528 | -$304,500 | -$26,689 | -$56,193 | -$195,253 | -$411,191 |
| Bio-based Feedstocks | $4,586 | $9,031 | $60,066 | $127,288 | $277,665 | $595,140 | $59,934 | $126,773 | $397,658 | $941,027 |
| Total Annual Impact | $1,727 | $3,032 | $41,981 | $90,375 | $236,492 | $530,456 | $41,378 | $88,704 | $328,463 | $830,826 |
| Investment (Non-annual) | $1,570 | $3,344 | $15,547 | $32,248 | $508,477 | $962,418 | $15,547 | $32,248 | $652,288 | $1,249,153 |

# Integrating IMPLAN with a National Agricultural Policy Model

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## INTRODUCTION

Economic impacts resulting from national policy changes can be evaluated using state IMPLAN models. Numerous publications have taken results from a national model and used those results in showing what impacts would occur to a state or a region's economy. However, what happens when you wish to take the impacts from an interregional multi-state model that is national in scope to examine the potential impacts changes in policy has on the nation's economy? An option explored in this proposed paper is an interface developed between POLYSYS, a 305 agricultural supply region econometric model, and IMPLAN. The interface takes POLYSYS acreage, price, and cost output and makes two major changes to IMPLAN databases. First, the program adds an energy crop sector to IMPLAN based on production and cost information supplied by POLYSYS for each of the 48 contiguous states. Next, agricultural impacts that occur as a result of projected changes in the agricultural sectors are placed in each state's IMPLAN model incorporating the POLYSYS projected changes in crop production, prices, and income.

The integrator, written in Visual Basic and taking advantage of IMPLAN's data structure, provides the user a means to solve IMPLAN at the state level and determine regional economic impacts as a result of changes in agricultural production practices, policies, prices, government payments, and/or technology adoption. The integrator was used to automate the insertion of data into IMPLAN, running the model, and conducting the economic impacts. The resulting reports generated from the analysis summarize, via graphs and maps, the economic impacts as measured by changes in total industry output, employment, and value added.

## METHODS USED

The analysis uses the output from POLYSYS, an agricultural policy simulation model of the U.S. agricultural sector that includes national demand, regional supply, livestock, and aggregate income modules[1] and integrates that output into IMPLAN through the POLYSYS IMPLAN Integrator (PΠ). POLYSYS is anchored to published baseline projections for the agricultural sector, and the model simulates deviations from the baseline. POLYSYS uses a 10 year USDA baseline for all crop prices and supplies except hay, which is taken from the Food and Agriculture Policy Research Institute (FAPRI) baseline for U.S. agriculture. The POLYSYS model includes the eight major crops (corn, grain sorghum, oats, barley, wheat, soybeans, cotton, and rice) as well as switchgrass and hay (alfalfa and other hay). POLYSYS is structured as a system of interdependent modules of crop supply, livestock supply, crop demand, livestock demand and agricultural income. POLYSYS' crop supply module consists of 305 independent linear programming models corresponding to the Agricultural Statistical Districts (ASD). Each ASD is characterized by relatively homogeneous production. The purpose of the crop supply module is to allocate acreage at the regional level to the modeled crops, given baseline information on regional acreage of the model crops, regional enterprise budgets of each crop, lagged prices and a set of allocation rules. The supply modules are solved first, then crop and livestock demand are solved simultaneously, followed by the agricultural income module. Changes that occur from the baseline are estimated and provide input to IMPLAN. Once IMPLAN is solved, information at the state level regarding changes in total industry output and employment is estimated for each sector of the economy.

Production, prices, and acreage from each of the 305 ASDs is determined independently and aggregated to obtain information at the state level for barley, corn, cotton, hay, oats, rice, sorghum, soybeans, switchgrass, and wheat. In addition, information on the cost of production of switchgrass by ASD is transferred from the POLYSYS solution. To incorporate the POLYSYS data into IMPLAN the following procedure was followed: 1) for each state's Access file, all links to the Master File (01NAT509.ims) were manually removed; 2) the change in Total Industry Output (TIO) was calculated for corn, sorghum, oats, barley, wheat, soybeans, cotton, and rice including changes in proprietary income and government payments; 3) for states growing switchgrass, TIO, Employment, Total Value Added (employee compensation), and the Gross Absorption Coefficients (GAC) were calculated for a new switchgrass industry; 4) Total Revenue (TR) from POLYSYS was equated to TIO and was calculated by multiplying the price of switchgrass by the quantity produced (yield multiplied by the number of acres); 5) TIO was inserted in the SAOutput table (code 24001); 6) the Gross Absorption Coefficients (GACS) were developed by dividing switchgrass input expenditures by TIO; 7) the individual GACs were inserted in both the US Absorption and Regional Absorption tables; 8) the sum of the GACs was inserted in the US Absorption Total table; 9) labor costs were assigned to Employee Compensation and was stored in the SAValue Added table (code 5001); and 10) the number of employees was inserted in SAEmployment table (code 20001).

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[1] De La Torre Ugarte, Daniel, Daryll E. Ray, and Kelly H. Tiller. "Using the POLYSYS Modeling Framework to Evaluate Environmental Impacts in Agriculture." *Evaluating Natural Resource Use in Agriculture*. Thyrele Robertson, Burton C. English, and Robert R. Alexander, ed., pp 151-172. Ames IA: Iowa State University Press, 1998.

Switchgrass is not currently produced as a dedicated energy source in the United States, although it is grown on some CRP acres and on hay acres as a forage crop. The lack of large-scale commercial production results in switchgrass not being identified in the IMPLAN model. Thus, its production must be added to the IMPLAN state models if POLYSYS projects switchgrass production to occur. This is achieved through a weighted aggregation scheme. Expenses by IMPLAN sector are summed over each region within the state and divided by total sales of switchgrass using the following equation:

$$GAC_{m,k,j} = \sum_{j=1}^{n}( COST_{i,j,k} * ACRE_{m,i,j}) / \sum_{j=1}^{n}(Q_{m,i,j} * P)$$

i = 1 to 48 for the number of states
j = 1 to n for the number of ASD's with in a state
k = 1 to 509 for the number of IMPLAN sectors
m = POLYSYS' solution year – 2005 through 2013
where:
$GAC_{m,k,i}$ is the gross absorption coefficient representing the amount spent in year (m) in sector (k) in state (i) per dollar of output,
$COST_{i,j,k}$ is the amount spent in IMPLAN sector (k) in state (i) and ASD (j) in dollars per acre,
$ACRE_{m,i,j}$ is the acres planted in switchgrass in year (m) for state (i) and ASD (j),
$Q_{m,i,j}$ is the quantity of switchgrass produced in year (m) for state (i) and ASD (j) in tons, and
P is the national price for switchgrass in dollars per ton.

These coefficients represented the state's bio-feedstock production function and were inserted into a blank industrial sector. The state model was run with a bio-feedstock total industry output equaling the gross returns determined from the POLYSYS solution for each ASD aggregated to the state. Please note that the economic activity that would result when the bio-feedstock is consumed is not modeled.

**Determining Regional Economic Impacts**

Regional impacts are divided into four areas in this study. These include the economic impacts resulting from the production of switchgrass, the change in acres of traditional crops, changes in government payments, and the price change of traditional crops. To capture the economic impacts as a result of changes in these important factors, the change in gross returns from traditional crops in POLYSYS is divided into two parts as a result of a change in acres and change in price. The change in acres impact reflects a change in total industry output and a reduction or increase in expenditures for agricultural inputs. This change is measured by subtracting the change in production when compared to the baseline at a given geographical location and multiplying the result by the baseline price.

$$\Delta TIO_{m,i,c} = \sum_{j=i}^{n} P^{b}_{m,i,j,c} * (Q^{s}_{m,i,j,c} - Q^{B}_{m,i,j,c})$$

c = 1 to 9 for the traditional crops in POLYSYS (barley, corn, cotton, hay, oats, rice, sorghum, soybeans, wheat)
m,k,i,j have been previously defined
where:

$\Delta TIO_{m,i,c}$ is the change in total industry output for year (m), state (i), and crop (c),
$P^{b}_{m,i,j,c}$ is the POLYSYS baseline price for year (m), state (i), ASD (j) and crop (c),
$Q^{s}_{m,i,j,c}$ is the quantity of crop (c) produced for scenario (s) and year (m), state i, and ASD (j), and
$Q^{b}_{m,i,j,c}$ is the quantity of crop (c) produced for the baseline and year (m), state i, and ASD (j).

This difference was treated as an impact to the industrial sector. The remainder of the change between the new scenario and the POLYSYS baseline was assumed to impact proprietor's income using the following:

$$\Delta PI_{m,i} = \sum_{c=1}^{9} \left( \sum_{j=1}^{n} \left( GR^{s}_{m,i,j,c} - \sum_{j=1}^{n} GR^{b}_{m,i,j,c} \right) - \Delta TIO_{m,i,c} \right)$$

where:
$\Delta PI_{m,i}$ is the change in proprietors' income for year (m), state (i),
$GR^{s}_{m,i,j,c}$ is the gross return for scenario (s), for year (m), state (i), ASD (j), and crop (c),
$GR^{b}_{m,i,j,c}$ is the gross returns for the baseline scenario, for year (m), state (i), ASD (j), and crop (c), and
$\Delta TIO_{m,i,c}$ has been defined elsewhere.

The impacts on proprietor's income were summed over each crop and the result was placed in the model, along with each crops individual total industry output impacts and the switchgrass gross returns. Finally, changes in government payments were determined for each ASD and crop and aggregated to the state level. Using IMPLAN, these impacts were modeled for each state.

**An Example: $50 Switchgrass Price, Year 2013**

Switchgrass acreage, change in net returns, economic impacts of growing and harvesting switchgrass (industry only), including the total economic impacts from growing and harvesting switchgrass (all industries) are presented in Figures 1 through 4. Much of the switchgrass production occurs in the Southern part of the United States with eastern Texas, Tennessee, Oklahoma, and Kansas leading the way. North Dakota also has a larger number of switchgrass acres in production. As a result of the shift in crop production away from traditional crops and into $50/dt switchgrass, each state in the nation shows an increase in net returns from agriculture commodities. These increases result from a decrease in traditional crop acreage planted, an increase in price, and, of course, increase in switchgrass acres, along with a decrease in government payments. These agricultural sectors changes impact the entire United States economy with all states, except California and Arizona, having positive impacts.

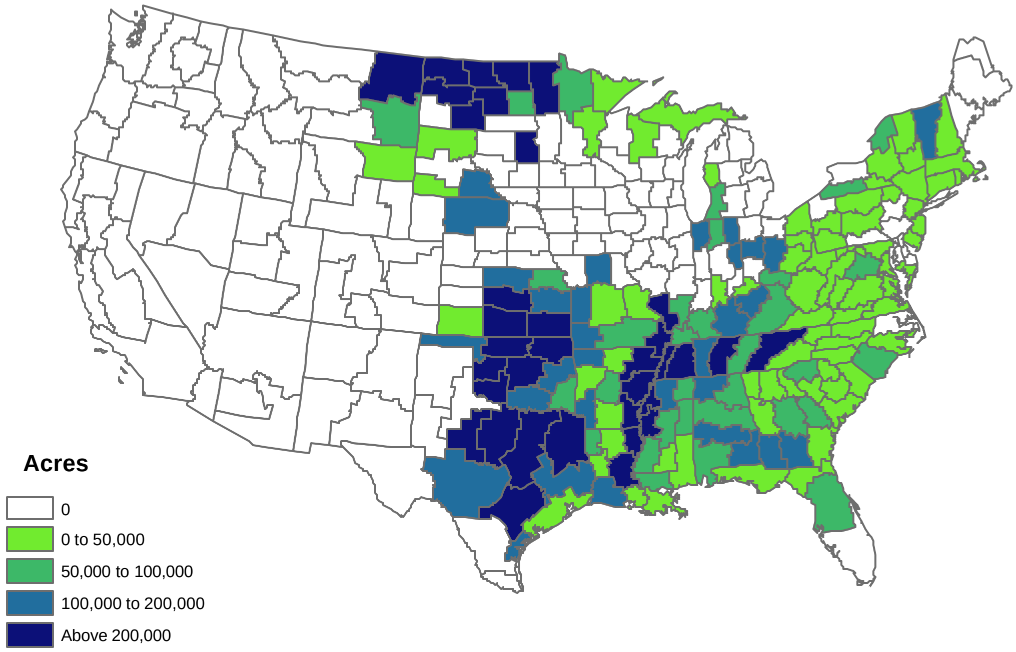


**Figure 1. Switchgrass Acreage at $50/dt, Year 2013.**

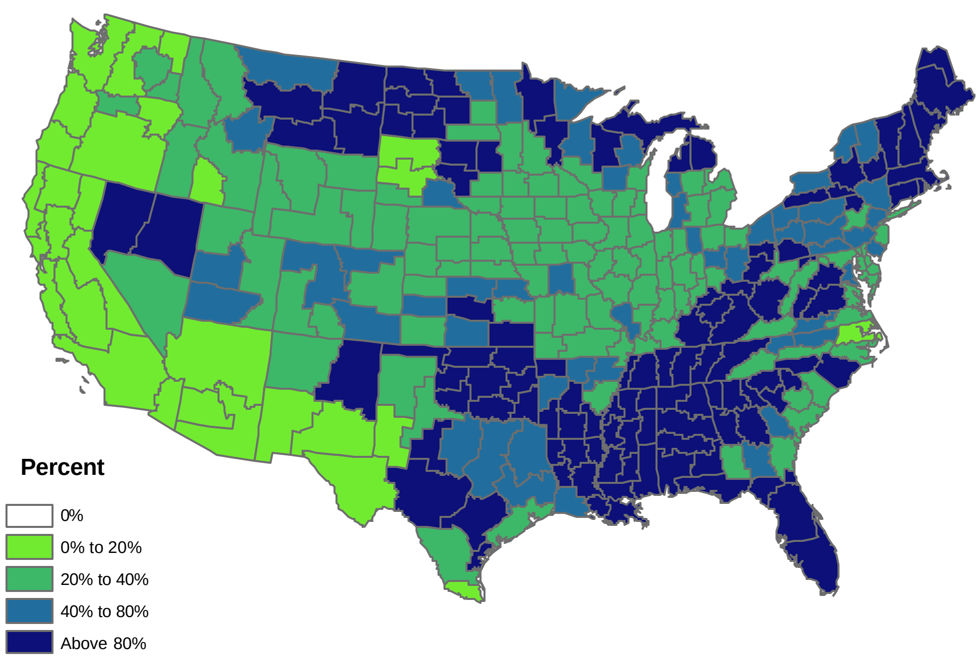

**Figure 2. Change in Net Returns, $50/dt, Year 2013.**

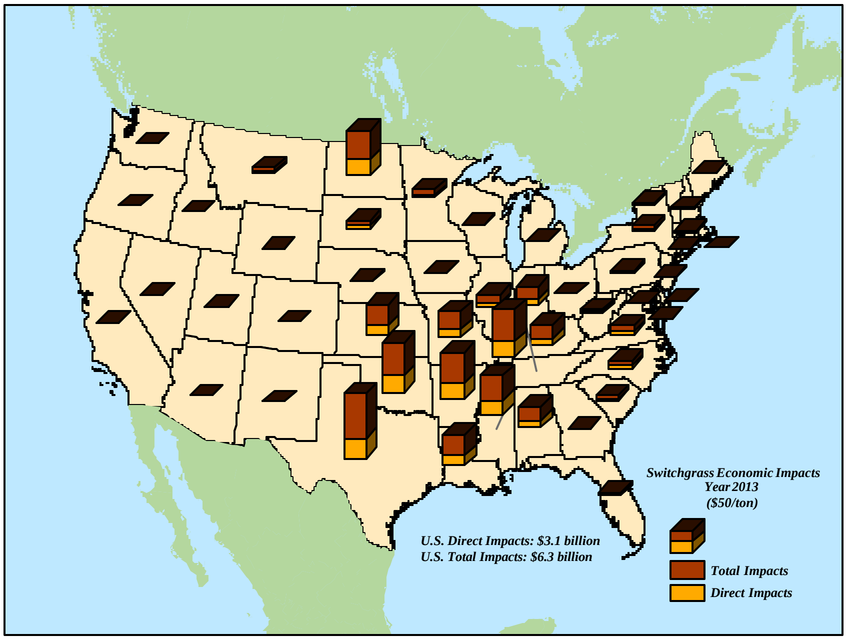


**Figure 3. Economic Impact of Growing and Harvesting Switchgrass, $50/dt, Year 2013.**

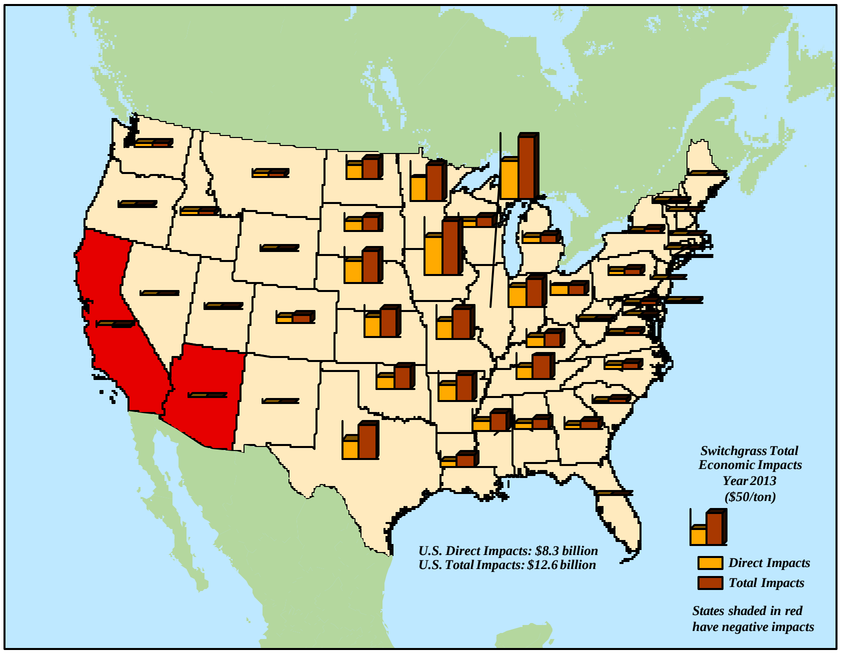


**Figure 4. Total Economic Impacts for Switchgrass, $50/dt, Year 2013.**

## Summary and Conclusions

This analysis uses the output from POLYSYS, an agricultural policy simulation model of the U.S. agricultural sector that includes national demand, regional supply, livestock, and aggregate income modules and integrates that output into IMPLAN through the POLYSYS IMPLAN Integrator (PΠ). The integrator, written in Visual Basic and taking advantage of IMPLAN's data structure (sample screens (Figures 5-8) shown below), provides the user a means to solve IMPLAN at the state level and determine regional economic impacts as a result of changes in agricultural production practices, policies, prices, government payments, and/or technology adoption. Integrating the output into IMPLAN allows time saving, the reduction in the potential for mistakes, the examination of more complex issues, a more complete evaluation of data, and the undertaking of larger projects.

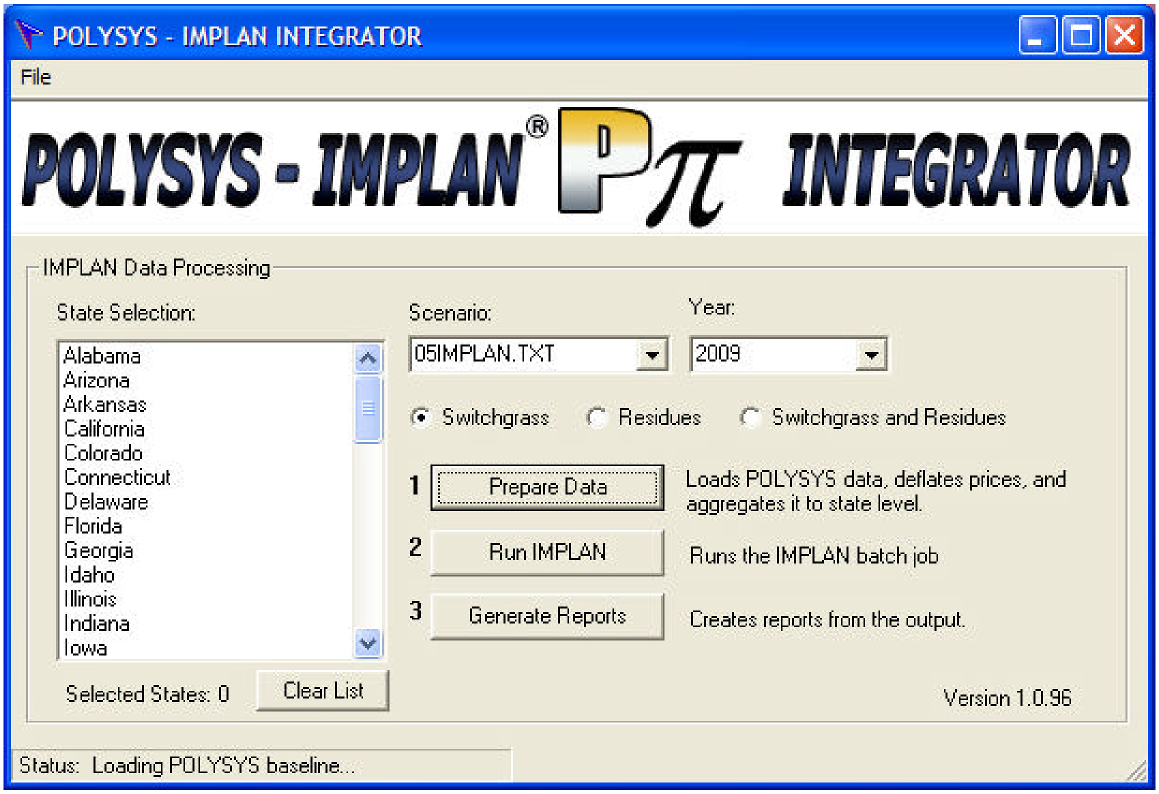


Figure 5. Main Screen of the POLYSYS IMPLAN Integrator (P Π )—Model is Loading POLYSYS Data, Deflating Prices, and Aggregating to the State Level.

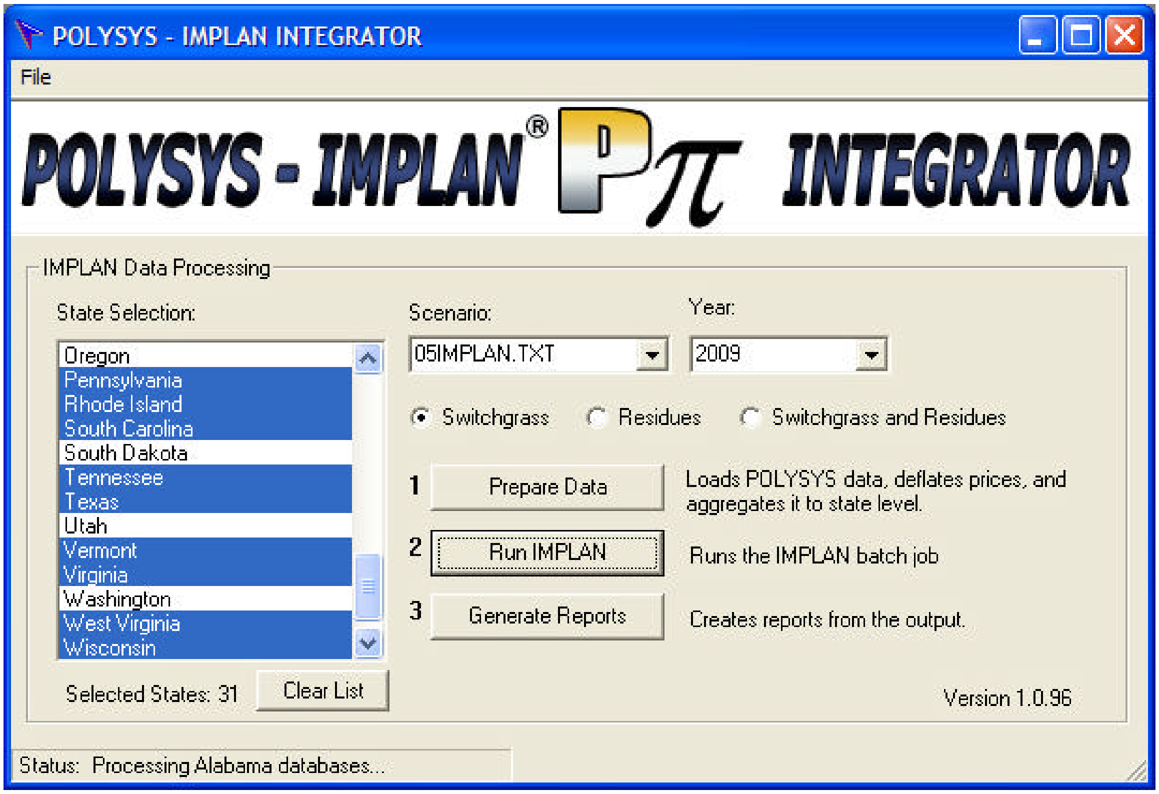


Figure 6. Main Screen of the POLYSYS IMPLAN Integrator (P Π )—Model has Prepared Data for Switchgrass States (Highlighted) and is Initializing the IMPLAN Runs.

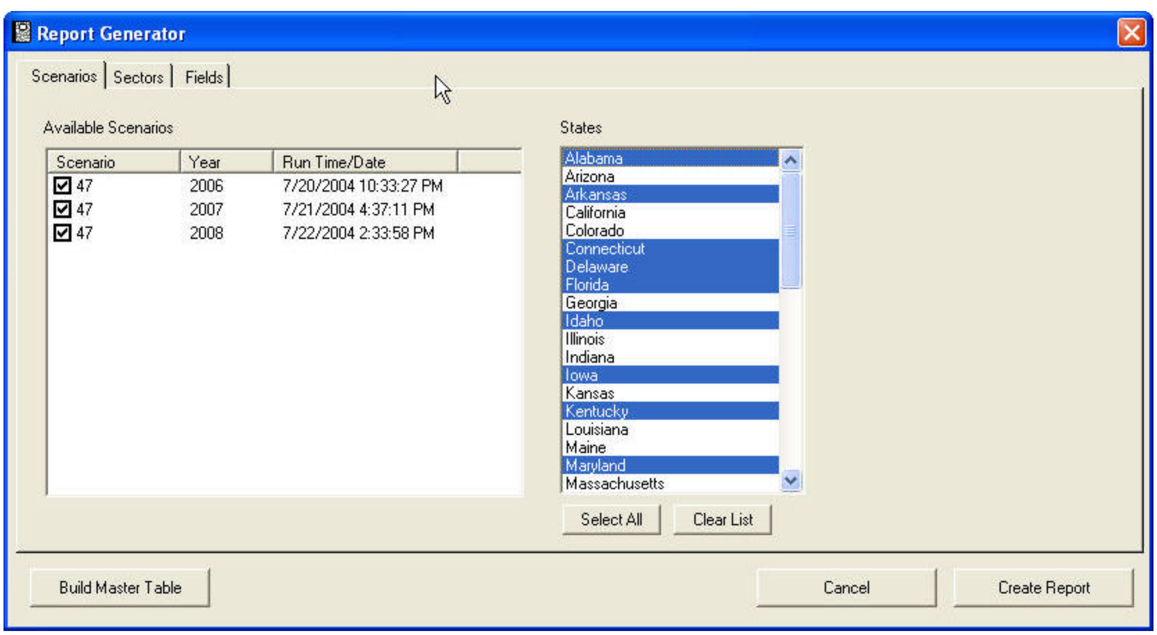


Figure 7. Report Generator Scenario Screen—Scenario and Years Chosen, Including States.

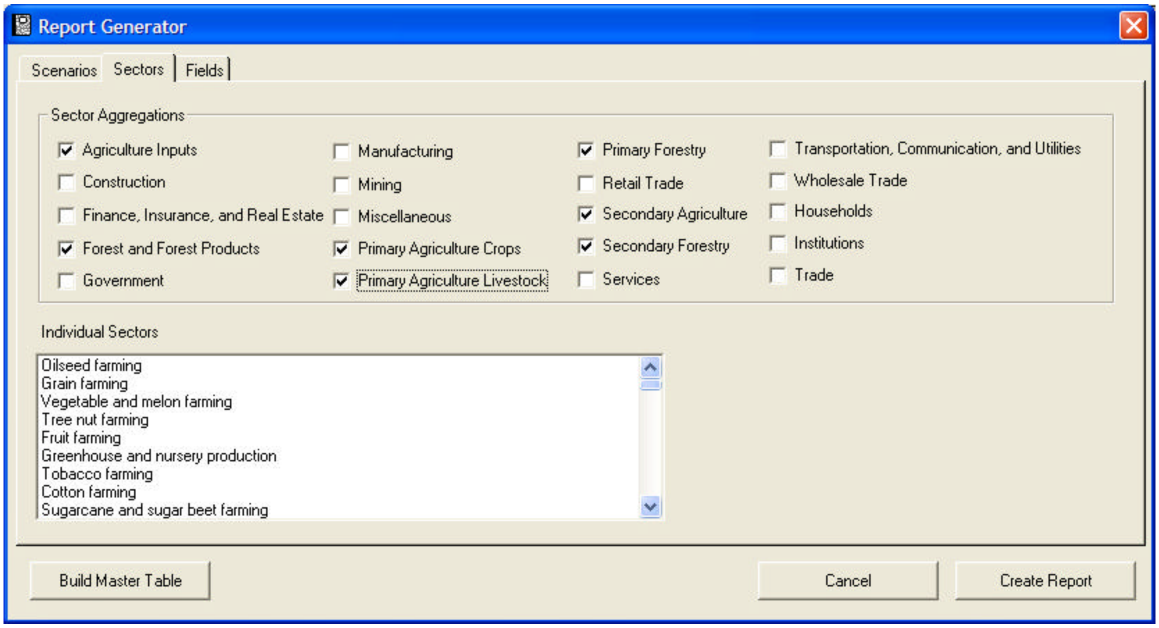


Figure 8. Report Generator Sector Screen—Reports Generated via Various Sector Aggregations.

# Using IMPLAN for Forest Policy Analysis in Maine

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## INTRODUCTION

Maine is the nation's most heavily forested state (90% of its land covered with forests), with more of its forest (96%) privately owned, and more of its forest (95%) classified as commercial timberland than any other state. Until 2003, Maine held more acres of industrial forestland than any other state. With a growing trend in sales from forest industry to institutional owners (pension funds, timber investment management organizations), it now ranks third behind Oregon and Alabama. Maine's forests rank 10th among the 50 states in standing volume of merchantable softwood timber. At the same time Maine, "Vacationland", is within a day's drive of 60 million people, 21% of the population of the United States, as well as millions of Canadians. Forest-based recreation, including hunting and fishing, attracts hundreds of millions of tourist dollars to the state each year. In 2001, the Forestry Sector accounted for 10 percent of Maine's economic output, 3.35% of its employment, 5.04% of employee compensation, 9.5% of gross state product and 22.22% of the value of exports of all products and services. Industry output totaled $6.3 billion, with a total economic impact of $10.2 billion. Employment in the sector totaled 27,000, but the sector supported more than 51,000 jobs in the state overall. For many years, the Forestry Sector has accounted for nearly one-third of all Maine manufacturing employment and wages and more than half of all capital expenditures in manufacturing. With forest industries that dominate the state's manufacturing sector, more than a century of forest-based recreation and tourism, the largest area of privately owned wild land in the eastern U.S., and a peculiar geographic placement (bordering only one other state), Maine's forests have become a focus of intense policy debate.

### CASE 1. TRADEOFFS IN A PUBLIC TIMBER SALE DECISION

Maine's "Public Reserved Lands", similar to "state forests" in other states, are managed by the State for multiple forest resources values. However, all of the money needed to manage these lands comes from timber sales. In the early 1990s, foresters responsible for the Four Ponds Unit in western Maine were preparing an area of spruce and fir timber for sale. They faced a dilemma. Markets existed for the lower quality spruce and fir logs at both local sawmills and a local paper mill. Market conditions were such that the paper mill was paying more for this roundwood than were the sawmills. The foresters, mindful of their mandate to manage the lands to best meet the interests of the people of Maine, wondered which market would offer the greatest potential benefit to the State.

I provided the decision makers with IMPLAN multipliers (Table 1) that indicated that selling the timber to the sawmills would have a greater multiplier effect than selling to the paper mill for employment, value added in manufacture, total income, personal income, and value of output. It seemed clear that sale to the sawmills would have the greatest benefit. However, the decision was complicated by the fact that all of Public Reserved Lands are managed for multiple uses--timber, recreation, wildlife habitat, water quality--but the only source of revenue is timber sales. So, if the wood were sold to the sawmills, the benefits of higher multipliers would be offset by lower revenue available for boat ramps, picnic tables, trail maintenance, etc.

So, what did the land managers do? The paper mill won the bid but negotiated a "high grade" price that reflected log value as well as pulp value. The timber was sold tree-length and the buyer sent the higher grade material to sawmills and used the lower grade material for pulp.

## CASE 2. RIPPLE EFFECTS OF PAPER INDUSTRY DECISIONS

Maine is one of the leading paper-producing states. It's production is dominated by printing and writing grades of paper. These grades are subject to increasing global competition and Maine's mills are owned by multi-national and, increasingly, Canadian corporations. Pulp and paper manufacturers have dominated Maine's Forestry Sector for more than a century. Their presence and contribution to the State's economy are easy to take for granted, but a growing awareness of global competitive pressures has renewed public interest in understanding just how dependent various economic sectors are on this industry.

Table 1. Multipliers for Franklin County, Maine. 1990 IMPLAN Data Base

| | | |
|---|---|---|
| 1. EMPLOYMENT (TOTAL JOBS) | | |
| SECTOR | TYPE I MULTIPLIER | TYPE II MULTIPLIER |
| 134 SAWMILLS | 1.5786 | 2.2122 |
| 162 PAPER MILLS | 1.3746 | 1.9264 |
| | | |
| 2. VALUE ADDED IN MANUFACTURE | | |
| SECTOR | TYPE I MULTIPLIER | TYPE II MULTIPLIER |
| 134 SAWMILLS | 1.5818 | 2.1521 |
| 162 PAPER MILLS | 1.2135 | 1.4344 |
| | | |
| 3. TOTAL INCOME | | |
| SECTOR | TYPE I MULTIPLIER | TYPE II MULTIPLIER |
| 134 SAWMILLS | 1.5665 | 2.0625 |
| 162 PAPER MILLS | 1.2023 | 1.3956 |
| | | |
| 4. PERSONAL INCOME | | |
| SECTOR | TYPE I MULTIPLIER | TYPE II MULTIPLIER |
| 134 SAWMILLS | 1.4446 | 1.8187 |
| 162 PAPER MILLS | 1.1465 | 1.2844 |
| | | |
| 5. OUTPUT | | |
| SECTOR | TYPE I MULTIPLIER | TYPE II MULTIPLIER |
| 134 SAWMILLS | 1.5205 | 1.7953 |
| 162 PAPER MILLS | 1.1529 | 1.2728 |

In order to increase awareness of the dependency of many Maine economic sectors on the paper industry, I used the IMPLAN data base and multiplier values to describe the impacts on Maine as a whole, and on Penobscot County, of a complete collapse of the industry. The analysis was intended to be an attention-getter, rather than a forecast of something that is likely to happen, but the recent closure of several paper mills (including one with more than a century of operation in Maine) has made the information more interesting to policy makers than it might have been a decade ago.

Table 2 presents some information on the shares of Maine's and Penobscot County's economies that are accounted for by the paper industry.

Table 2. Paper Industry Shares of Maine and Penobscot County Economies, 1990 and 2001.

| | Total Maine | Percent of Maine |
|---|---|---|
| 1990 jobs | 15,524 | 2.2 |
| 2000 jobs | 13,152 | 1.6 |
| 1990 value added | $1,094.48 million | 4.9 |
| 2000 value added | $1,374.09 | 3.9 |
| 1990 exports | $2,953.7 million | 25.3 |
| 2000 exports | $3,669.269 million | 15.4 |
| | Total Penobscot County | % of Penobscot County |
| 2000 jobs | 2,994 | 3.3 |
| 2000 value added | $291.47 million | 7.4 |
| 2000 exports | $553.43 million | 17.6 |

If Maine's paper industry had simply disappeared in the year 2000, Maine would have lost (total impact--direct, indirect, and induced):

34,255 jobs (4.25% of state total)

$2,266,071,000 in value added (6.34% of state total)

8.7% of the value of all exports of products and services from Maine

With the total loss of the County's paper industry, Penobscot County would have lost:

8,883 jobs (9.8% of the County total)

14.2% of County value added

Policy makers and the general public have no problem understanding that, if a paper mill closes, paper mill workers lose their jobs. Although the above numbers are impressive, it is perhaps even more effective to provide some idea of the extent to which the paper industry is connected to other sectors of the economy. If Maine's paper industry had been lost in 2000, other sector job losses would have included the examples shown in Table 3.

Table 3. Examples of Jobs Dependent on Maine's Paper Industry in 2000

| Industry | Dependent Jobs |
|---|---|
| Logging | 1,080 |
| Sawmills | 570 |
| Motor Freight Transport | 1,578 |
| Railroads | 171 |
| Electrical Services | 277 |
| Wholesale Trade | 1,996 |
| General Merchandise Stores | 435 |
| Food Stores | 558 |
| Eating and Drinking Establishments | 1,423 |
| Banking | 246 |
| Credit Agencies | 315 |
| Hotels, Lodging Places | 595 |
| Beauty and Barber Shops | 141 |

## CASE 3. FEDERAL LABOR POLICY IMPACTS ON MAINE'S FORESTRY SECTOR

"(C) An H-2A classification applies to an alien who is coming temporarily to the United States to perform agricultural work of a temporary or seasonal nature. " "An H-2B nonagricultural temporary worker is an alien who is coming temporarily to the United States to perform temporary services or labor, is not displacing United States workers capable of performing such services or labor, and whose employment is not adversely affecting the wages and working conditions of United States workers." (U.S. Citizenship and Immigration Services, Dept. of Homeland Security, 2004)

Maine's Forestry Sector has used significant numbers of H2B workers in timber harvesting for years. Due to mechanization of timber harvesting and improved road networks in the state, the number of Canadian bonded woods workers certified to work in the Maine woods has declined from more than 6,000 in 1954 to fewer than 1,000, but companies in northern and western Maine still rely strongly on these temporary workers during the peak harvesting season. However, in Fiscal 2004, the Department of Homeland Security set a national quota of 66,000 on these temporary work visas. That limit was reached in the spring of 2004, before H2B workers had been hired for the summer logging season in Maine.

Industry estimated a need for some 700 H2B workers in northern and western Maine, with about 450 engaged directly in timber harvesting. If unable to obtain H2B workers, or to find substitutes, the industry estimated a loss of 17% of sawlogs to sawmills and a 19% shortfall in raw material to the paper industry.[1] Using the 2001 IMPLAN data base for Maine, I applied these estimates to calculate total (direct, indirect, and induced) economic impacts on the state:

| | |
|---|---|
| Total jobs lost | 8,956 |
| Total payroll lost | $304 million |
| Total output lost | $1.5 billion |

Of course, these impacts presume actual shut-downs of forest operations and no possibility of raw material substitutions from other sources. Some Maine labor interests claim that the H2B workers are not needed. Rather, the industry should be paying domestic workers more for their services. However, although industry representatives who contributed to the raw material loss estimates no doubt wished to advocate for their interests, it does appear that the timing of a national labor policy change did make it difficult for the industry to adjust in time to prevent losses. There appears to be no evidence that a Maine mill has actually shut down during 2004 because of a lack of roundwood, but some are reported to be operating on no more than a week's supply.

Maine's forest products industries lobbied the state's congressional delegation to seek increases in the H2B quota cap, but neither the Department of Homeland Security nor the Department of Labor were willing to change the number. The industry gave some thought to using H2A visas (not limited) for the needed woods workers, but decided that if loggers were admitted under H2A then, likely, planters and tree thinning workers would be so classified. The industry does not want to pay H2A benefits for those workers.

## CONCLUSION

These three case studies illustrate rather simple ways in which IMPLAN data and impact analyses can be used to inform forest policy makers and others with an interest in this important economic sector. The analyses are somewhat simplistic, and one might argue that estimated losses could be mitigated over time. However, the information provided served a valid purpose of reminding decision makers of the interconnectedness of economic sectors, and the dangers of forgetting those links.

[1] Data compiled by Lloyd C. Irland, The Irland Group, Winthrop, Maine.

# Using Stated Preference Choice Experiments to Forecast the Economic Impacts of Recreational Fishing Policies.

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## INTRODUCTION

The National Marine Fisheries Service (NMFS) has periodically collected travel cost demand model data since 1994 using the Marine Recreational Fishing Statistical Survey (MRFSS). This data has been used to estimate site choice random utility models (RUM) to examine the value of site access and the value of catch rate changes in the North Atlantic, Mid Atlantic, South Atlantic, and Gulf Coasts [1, 2, 3]. These analyses have been very useful in determining the value of access to saltwater recreational fishing and analyzing the value of changes to the catch and/or keep rate across broad species groups. Unfortunately, due to the nature of the MRFSS, species-specific valuation models have proven difficult to estimate for all but the most popular species. Also, due to the lack of adequate variation in fisheries regulations across the years NMFS has collected this data, it has been impossible to model welfare changes stemming from policies, even across species with adequate sample. Additionally, because the MRFSS is an intercept survey, only anglers that have already decided to take a recreational fishing trip are interviewed, therefore it will never be possible to estimate entry and exit. This leaves these RUM models very useful for environmental damage assessment and regional or national total value estimates, but of very little use for analyzing typical recreational policies like bag limits, minimum size limits, and seasonal closures [4].

To address these shortfalls in the site choice models, NMFS turned to stated preference choice experiments (SPCE) in 2000 with the launch of a single species SPCE covering summer flounder in the Northeast. This survey worked quite well, allowing NMFS to examine changes in welfare and effort resulting from changes in bag limits, size limits, and season lengths [4]. Additionally, SPCE's have also been utilized in Alaska for halibut and salmon fishing trips [5]. The most recent effort in Alaska used a catch attribute containing a mix of halibut and various species of salmon catch. This was not a branded SPCE design but did allow substitution of different species targets when the regulations for another species changed. This paper focuses on NMFS' efforts to incorporate the successes with these previous efforts and expand the agency's focus regarding species substitution. These SPCE surveys involve extensive qualitative research to develop, taking considerable time and money. By including multiple species, it is hoped that cost and time outlays can also be reduced while improving policy analysis through the explicit inclusion of species substitution. The current effort focuses on four species or species groups; Epinephelus and Mycteroperca species group, Lutjanus Campechanus, Scomberomorus Cavalla, and Coryphaena species group (hereinafter grouper, red snapper, king mackerel, and dolphin respectively). Groupers were aggregated because they are regulated together and anglers, during the qualitative phase of this survey, were rarely able to distinguish individual species. The two dolphin species were aggregated because they are not differentiated by anglers or in the regulations.

## METHODOLOGY

Random utility theory underpins the analysis of SPCE data. An angler chooses a fishing trip from the set of all trips in the experimental design X if the utility of taking that trip is greater than the utility of taking any other trip in his or her choice set. The indirect utility of taking trip j is

$$U_j\left(X_j, e_j\right) = V_j\left(X_j\right) + e_j \qquad \text{(Eq. 1)}$$

where $V_j$ is the deterministic portion of utility, X contains trip cost, total catch of target species, target species catch of legal size, target species keep, catch of non-target species, target specific recreational fisheries policies, and $\varepsilon_j$ is the unobservable portion of indirect utility. Including a policy, as a direct utility argument, can be very convenient as the outcome, expressed as a change in catch and keep, of any recreational fisheries policy is not always readily available or even known. Denoting the set of all alternatives faced by an angler by S = {1,…,N} as the global choice set, an angler will choose trip j from S if

$$V_j\left(X_j\right) + e_j \geq V_k\left(X_k\right) + e_k,\ j \in S, \forall k \in S_i, S_i \subset S \qquad \text{(Eq. 2)}$$

the indirect utility of taking trip j is greater than the indirect utility of taking trip k for all trips in the individual's choice set. In this experimental design, anglers were presented eight paired comparisons using species target to define the type of trip taken. Since the experimental design contained four species, not all species were available in each choice experiment, and, therefore, each angler faced their own choice set, $S_i$. The random portion of the random utility model stems from the unobservable portion of indirect utility, captured here in the error term $\varepsilon_j$. If this error term is assumed be distributed in a type I extreme value distribution, the above trip choice framework can be modeled with the conditional logit model. S.Maddala [6] gives a complete derivation of the conditional logit model. Within this framework the probability that i takes trip j is given by

$$P_i(j) = P(j \mid j \in S) = \frac{e^{V_j(X_j)}}{\sum_{k \in S_i} e^{V_k(X_k)}} \qquad \text{(Eq. 3)}$$

Because the goal of this paper is to examine the impacts of policies on anglers, compensating variation (CV) for a hypothetical policy change will be calculated. This expression for CV is taken from Haab and McConnell's book [7] examining the value of quality improvements in the demand for recreation.

$$CV = \frac{\ln\left(\sum_{k \in S_i} e^{\left(-b_y TC_k + q_k^1 b_k\right)}\right) - \ln\left(\sum_{k \in S_i} e^{\left(-b_y TC_k + q_k^0 b_k\right)}\right)}{b_y} \qquad \text{(Eq. 4)}$$

where trip cost for the $k^{th}$ trip is represented by $TC_k$ and all other trip quality attributes from X are included in $q_k$, with the superscript 0 denoting the initial condition and the superscript 1 denoting the condition after the change in one or more of the quality attributes. In this case, the total number of attributes in X is seven. The researcher controls the attribute levels in X and these attribute levels were assigned based on conversations with fishery managers, analysis of MRFSS catch data, analysis of MRFSS expenditure data, and through the qualitative phase of the project. It was decided to present anglers with paired trips and a no trip option to choose from in each choice experiment. Incorporating the seven attributes from both trips into the sample design results in 14 factors, four with three levels and 10 with four levels, creating a full factorial of around 85 million possible combinations. Obviously, it would be impossible to present any sample the full factorial. Some subset of the factorial must be selected and a fractional factorial maintains the same statistical properties of the full factorial if it is balanced and orthogonal.

When each level of each factor occurs with the same frequency, a design is balanced and, when all parameters to be estimated are uncorrelated, a design is orthogonal [8]. For large designs with restrictions on the combinations of levels that can occur simultaneously, perfect balance and orthogonality, jointly defined as design efficiency, are difficult to achieve. Instead, efficiency can be measured relative to perfect balance and orthogonality and a design selected based on optimization of an efficiency criterion. One such criteria that was used for this design is D-efficiency. This criterion sets out to minimize estimate variance resulting from the fractional factorial selected. Since the estimable effects of concern here all stem from the conditional logit model described above, D-efficiency is a function of the covariance matrix Γ, as taken from Kuhfeld [8]:

$$\Sigma = \left(Z'PZ\right)^{-1} = \left[\sum_{j=1}^{S}\sum_{k=1}^{S_i} z'_{kj}\, P_{kj}\, z_{kj}\right] \qquad \text{(Eq. 5)}$$

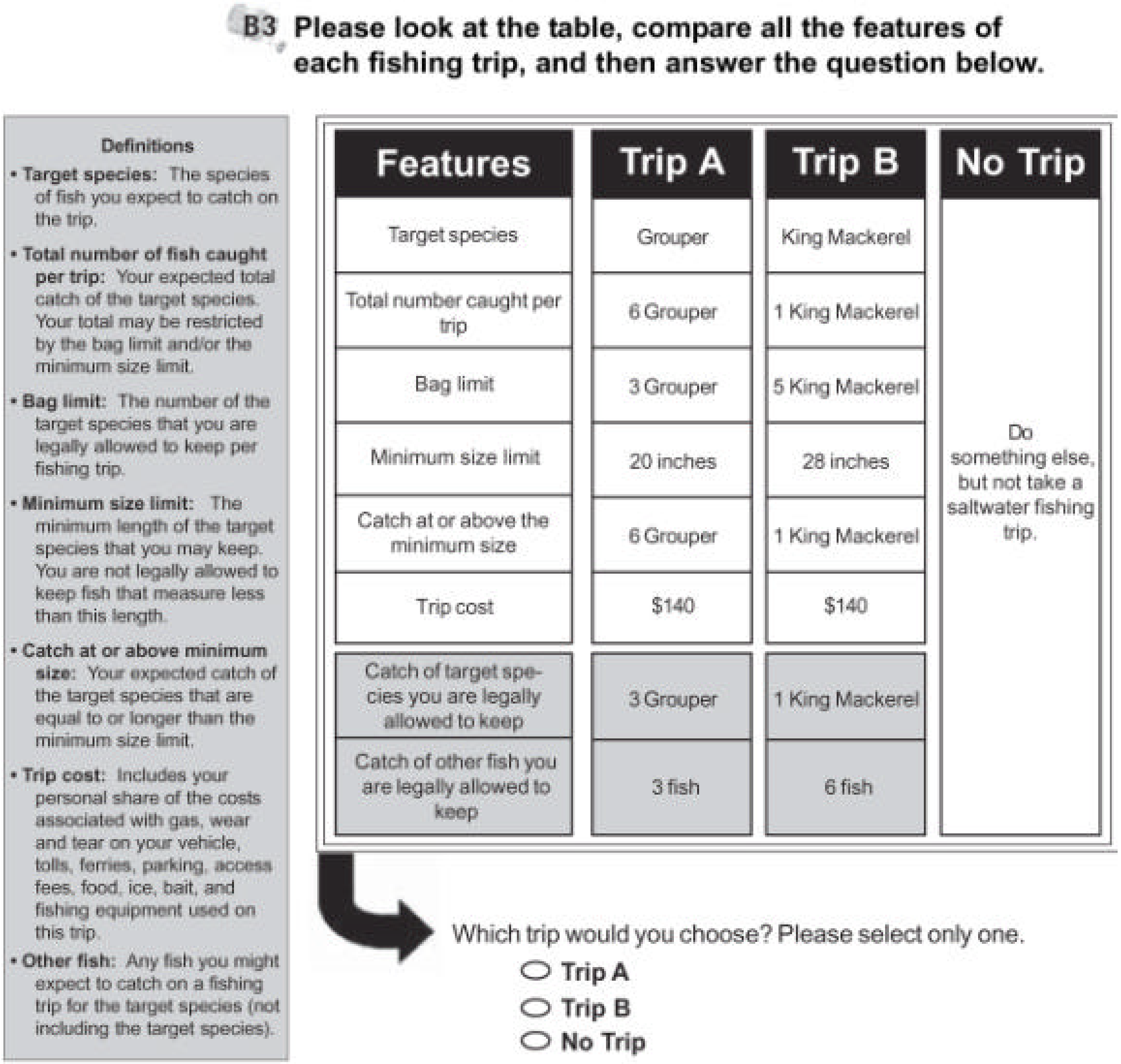
where $z_{kj} = x_{kj} - \sum_{i=1}^{S_i} x_{ij} P_{ij}$

$$\text{D-efficiency} = 100 \times \frac{1}{|\,\Sigma\,|^{\frac{1}{G}}} \qquad \text{(Eq. 6)}$$

Where G is the number of parameters in $P_{ij}$. From these equations, one can see that the covariance and therefore the efficiency criterion are functions of the parameters that are to be estimated using the survey data to be generated by this experimental design. As a result, a linear form of the efficiency criterion was used here rather than making restrictive assumptions regarding the value of unknown parameters.

$$\text{Linear D-efficiency} = 100 \times \frac{1}{K\,|\left(X'X\right)^{-1}|^{\frac{1}{G}}} \qquad \text{(Eq. 7)}$$

where K is the total number of trip combinations in the global choice set, S. Kuhfeld's [8] SAS experimental design macros were used as a framework for constructing the experimental design used for this survey. Kuhfeld's procedure involves four basic steps. The first involves recommending the optimal factorial size taking into account the number of attributes, number of attribute levels and the number of choices each angler will be expected to make. During the qualitative phase it was determined that anglers could handle as many as 8 choices per instrument and this phase recommend a design with 384 runs using 48 blocks, or different survey instruments. The next phase involve selecting a design based on the D-efficiency criteria while accounting for any restrictions that need to be imposed on the design. Three basic restrictions were imposed here; no strictly dominated trips could be allowed, legal catch could not be larger than total catch, and, for comparisons between trips with the same target, if the minimum size in trip one was less than the minimum size in trip two, the proportion of legal sized fish to total catch in trip one must be greater than that ratio in trip two and vice versa. All second order effects were included and one third level effect, species x legal catch x minimum size, was included. The third phase involved evaluating the design and several iterations were made to find a design that maximized D-efficiency while controlling the correlation between attributes. The final design, while not perfectly balanced or orthogonal, had very low levels of correlation between attributes with only legal catch and total catch slightly correlated. In reality these factors are correlated, but the correlation here stems from the restriction that total catch must always exceed legal catch. Finally, the design was blocked into 48 blocks by assigning a blocking factor that was totally uncorrelated with any other factor in the design.



**B3 Please look at the table, compare all the features of each fishing trip, and then answer the question below.**

Definitions

- **Target species:** The species of fish you expect to catch on the trip.
- **Total number of fish caught per trip:** Your expected total catch of the target species. Your total may be restricted by the bag limit and/or the minimum size limit.
- **Bag limit:** The number of the target species that you are legally allowed to keep per fishing trip.
- **Minimum size limit:** The minimum length of the target species that you may keep. You are not legally allowed to keep fish that measure less than this length.
- **Catch at or above minimum size:** Your expected catch of the target species that are equal to or longer than the minimum size limit.
- **Trip cost:** Includes your personal share of the costs associated with gas, wear and tear on your vehicle, tolls, ferries, parking, access fees, food, ice, bait, and fishing equipment used on this trip.
- **Other fish:** Any fish you might expect to catch on a fishing trip for the target species (not including the target species).

| Features | Trip A | Trip B | No Trip |
|---|---|---|---|
| Target species | Grouper | King Mackerel | Do something else, but not take a saltwater fishing trip. |
| Total number caught per trip | 6 Grouper | 1 King Mackerel | |
| Bag limit | 3 Grouper | 5 King Mackerel | |
| Minimum size limit | 20 inches | 28 inches | |
| Catch at or above the minimum size | 6 Grouper | 1 King Mackerel | |
| Trip cost | $140 | $140 | |
| Catch of target species you are legally allowed to keep | 3 Grouper | 1 King Mackerel | |
| Catch of other fish you are legally allowed to keep | 3 fish | 6 fish | |

Which trip would you choose? Please select only one.

- Trip A
- Trip B
- No Trip

**Figure 1. Sample choice experiment from survey.**

As mentioned previously, qualitative development work involved 12 focus groups in three different locations in the study area, Charleston, South Carolina, Miami, Florida (FL), and Tampa, FL, and 20 cognitive interviews conducted in Miami, FL. Input from this qualitative work informed both the construction of the experimental design and the layout of the choice experiment itself. Figure 1 contains a shot of the choice experiment as presented to the anglers. Names and addresses for this survey were sourced from both the MRFSS intercept creel survey and the telephone survey of coastal households. The MRFSS survey is conducted throughout the year stratified by two-month waves and the mail survey mirrored this wave stratification. The mail survey followed a modified Dillman method [9], with the initial field or telephone contact substituting for the first mailing in the Dillman series. This methodology has resulted in a 48%

response rate across the first two waves of mailing. The analysis below utilizes 8,010 responses from 1,436 anglers.

## RESULTS

The model was estimated in LIMDEP using full information maximum likelihood techniques. Because of current debate centering around the inclusion of policies as direct arguments in utility functions, two models were estimated; one containing only policy attributes and one containing only catch and keep attributes. Initially both models performed poorly across the whole sample.

Table I. Descriptive Statistics

| Variable | Levels Used in Experimental Design | Mean | Standard Error |
|---|---|---|---|
| K_BAG | 1, 2, 3, 5 | 2.70 | 0.0227 |
| D_BAG | 6, 10, 15, 20 | 12.98 | 0.0857 |
| G_BAG | 1, 2, 3, 6 | 3.00 | 0.0295 |
| R_BAG | 1, 2, 3, 5 | 2.86 | 0.0238 |
| TC | $45, $70, $105, $140 | 59.92 | 0.3324 |
| OTHER | 1, 3, 6 | 2.22 | 0.0148 |
| K_KEEP | 1, 2, 3, 5 | 1.76 | 0.0153 |
| D_KEEP | 1, 3, 6, 10, 15, 20 | 6.70 | 0.0851 |
| G_KEEP | 1, 2, 3, 5, 6 | 1.97 | 0.0211 |
| R_KEEP | 1, 2, 3, 5 | 1.90 | 0.0173 |
| K_TOTAL | 1, 2, 3, 5 | 3.43 | 0.0230 |
| D_TOTAL | 1, 3, 6, 10 | 6.69 | 0.0541 |
| G_TOTAL | 1, 2, 5, 6 | 4.42 | 0.0302 |
| R_TOTAL | 1, 2, 3, 5 | 3.47 | 0.0240 |
| K_SIZE | 20", 24", 28" | 24.00 | 0.0504 |
| D_SIZE | 18", 20", 24" | 20.69 | 0.0403 |
| G_SIZE | 18", 20", 24" | 20.71 | 0.0395 |
| R_SIZE | 16", 18", 22" | 18.65 | 0.0400 |
| K_LEGAL | 1, 2, 3, 5 | 2.42 | 0.0217 |
| G_LEGAL | 1, 2, 3, 6 | 3.12 | 0.0319 |
| D_LEGAL | 1, 3, 6, 10 | 4.37 | 0.0522 |
| R_LEGAL | 1, 2, 3, 5 | 2.55 | 0.0235 |

The survey was sent to all anglers agreeing to participate regardless of their targeting preference from their most recent saltwater fishing trip. This was done for three reasons; one, to insure adequate sample size, two, to capture entry behavior from anglers not currently participating in these fisheries, and, three, targeting behavior on the most recent trip might not be indicative of usual targeting behavior. The mail survey included a question that asked anglers to rank their preference for targeting the species included here and that question was used to subset this data.

If an angler responded that they always, frequently, or sometimes targeted one or both of the species in the paired comparison, that comparison was retained. This sub setting significantly improved model fit, and Table I contains descriptive statistics for the attributes used in the model within this subset. The first initial of each target species is used to label the target species-specific attribute (i.e. k = king mackerel, d = dolphin, g = grouper, and r = red snapper).

It is difficult to test the appropriateness of such a subset, but a likelihood ratio test indicates the parameters generated using the whole data set and the data set containing only targeters were statistically different. Preliminary estimation of a parsimonious model nested along stated targeting preference indicates that the sub setting is appropriate. In this model, all species-specific constants for the non-targeters were insignificant indicating that anglers inexperienced with the target species included in the study did not consider target species, but instead focused on other attributes. Hereinafter, non-nested results after sub setting the data will be reported, with Table II containing the results from policy attribute model and Table III containing the results of the catch and keep model.

These two different models were estimated to demonstrate the difficulty in analyzing policy based strictly on angler's preferences for keep. Keep is function of the stock, size distributions within the stock, angler experience, and regulations; items difficult to know with certainty. Also, just because a there is a bag limit of two fish does not mean that an angler will always catch enough to fill his bag or even desire to fill his bag. Because experienced anglers have the ability to target larger sizes of fish, minimum size limits may not directly bind keep. Additionally, regulations have a stock effect so this relationship between keep and policies is inherently a dynamic one. As a result, there are no direct relationships between these policies and keep. Therefore, including policy attributes directly allows policy impacts to be simulated directly without the additional information required for keep. Finally, even if perfect information about size distributions and individual catch rates existed; anglers may also have separate preferences for the policy mechanism itself, which can only be incorporated by including policy attributes directly.

Not much can be drawn from the parameters of a conditional logit model directly. Instead the focus is on sign, significance and model fit. All variables in both models were significant, with the exception of king mackerel bag limit, which also has an unexpected sign. Both models are significant, with all parameters significantly different from zero using a likelihood ratio test. Additionally, the fit of both models, as measured by adjusted R-squared, is excellent. A Hausman test was conducted for every trip option included in both models. The Hausman test's maintained hypothesis states that the error distributional assumptions for the conditional logit model hold; that is there is no violation of the independence of irrelevant alternatives property. All trips in both models fail to reject the null at any reasonable level of significance.

All initial policy attribute models that included minimum size exhibited an unexpected positive sign. On would expect that a tightening of regulations would reduce utility. From the qualitative work, anglers view minimum size limits very differently and those varying preferences are perhaps reflected in the initial positive sign on this policy attribute. The same result was obtained in [4] and Hicks dealt with this apparent conflict by crossing minimum size with the number of legal sized fish to achieve a measure of the total inches of fish caught. In this analysis, this relationship was modeled as a quadratic, and those results are reported in Table II.

Table II. Policy Attribute Model Results.

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] |
|---|---|---|---|---|
| K_BAG | -0.0059 | 0.0215 | -0.2750 | 0.7829 |
| D_BAG | 0.0208 | 0.0068 | 3.0570 | 0.0022 |
| G_BAG | 0.1079 | 0.0177 | 6.0910 | 0.0000 |
| R_BAG | 0.1450 | 0.0227 | 6.3920 | 0.0000 |
| TC | -0.0053 | 0.0005 | -11.5250 | 0.0000 |
| OTHER | 0.0617 | 0.0083 | 7.4620 | 0.0000 |
| $K\_SIZE^2$ | -0.0027 | 0.0005 | -5.8320 | 0.0000 |
| $D\_SIZE^2$ | -0.0017 | 0.0008 | -2.2980 | 0.0216 |
| $G\_SIZE^2$ | -0.0026 | 0.0007 | -4.0110 | 0.0001 |
| $R\_SIZE^2$ | -0.0020 | 0.0008 | -2.6300 | 0.0085 |
| K_SIZE | 0.1223 | 0.0134 | 9.1020 | 0.0000 |
| D_SIZE | 0.0685 | 0.0191 | 3.5880 | 0.0003 |
| G_SIZE | 0.1189 | 0.0161 | 7.3670 | 0.0000 |
| R_SIZE | 0.0816 | 0.0177 | 4.6040 | 0.0000 |
| K_LEGAL | 0.2923 | 0.0241 | 12.1450 | 0.0000 |
| G_LEGAL | 0.1280 | 0.0161 | 7.9350 | 0.0000 |
| D_LEGAL | 0.0491 | 0.0111 | 4.4160 | 0.0000 |
| R_LEGAL | 0.1876 | 0.0229 | 8.2060 | 0.0000 |
| **Log-Likelihood** | | | -7129.98 | |
| **Log-Likelihood no coefficients** | | | -17601.97 | |
| **Log-Likelihood constants only** | | | -22945.64 | |
| Adjusted R-squared | | | 0.59448 | |

**Table III. Policy Outcome Model Results.**

| Variable | Coefficient | Standard Error | b/St.Er. | P[\|Z\|>z] |
|---|---|---|---|---|
| TC | -0.0023 | 0.0004 | -5.8300 | 0.0000 |
| OTHER | 0.1108 | 0.0076 | 14.5240 | 0.0000 |
| K_TOTAL | 0.2745 | 0.0189 | 14.5000 | 0.0000 |
| G_TOTAL | 0.1785 | 0.0141 | 12.6560 | 0.0000 |
| D_TOTAL | 0.0495 | 0.0091 | 5.4200 | 0.0000 |
| R_TOTAL | 0.1429 | 0.0194 | 7.3640 | 0.0000 |
| K_KEEP | 0.2589 | 0.0348 | 7.4330 | 0.0000 |
| G_KEEP | 0.2851 | 0.0276 | 10.3430 | 0.0000 |
| D_KEEP | 0.0201 | 0.0076 | 2.6560 | 0.0079 |
| R_KEEP | 0.2893 | 0.0327 | 8.8520 | 0.0000 |
| K_LEGAL | 0.2923 | 0.0241 | 12.1450 | 0.0000 |
| G_LEGAL | 0.1280 | 0.0161 | 7.9350 | 0.0000 |
| D_LEGAL | 0.0491 | 0.0111 | 4.4160 | 0.0000 |
| R_LEGAL | 0.1876 | 0.0229 | 8.2060 | 0.0000 |
| Log-Likelihood | | | -7223.69 | |
| Log-Likelihood no coefficients | | | -17601.97 | |
| **Log-Likelihood constants only** | | | -22945.64 | |
| Adjusted R-squared | | | 0.58935 | |

To further examine this quadratic relationship, Figure 2 plots angler utility as a function of the minimum size for the four target species. In this figure, the dotted vertical lines represent the minimum and maximum levels of minimum size included in the experimental design. All graphs show a preference for larger minimum sizes to some maximum level, at which point larger minimum sizes decreases utility. In this case, the maximums occur approximately at 20 inches for red snapper and dolphin, 22 inches for grouper, and 23 inches for king mackerel. Currently, the minimum size limit is 16 inches, 20 inches, 24 inches, and 24 inches for red snapper, dolphin, grouper and king mackerel respectively[a].

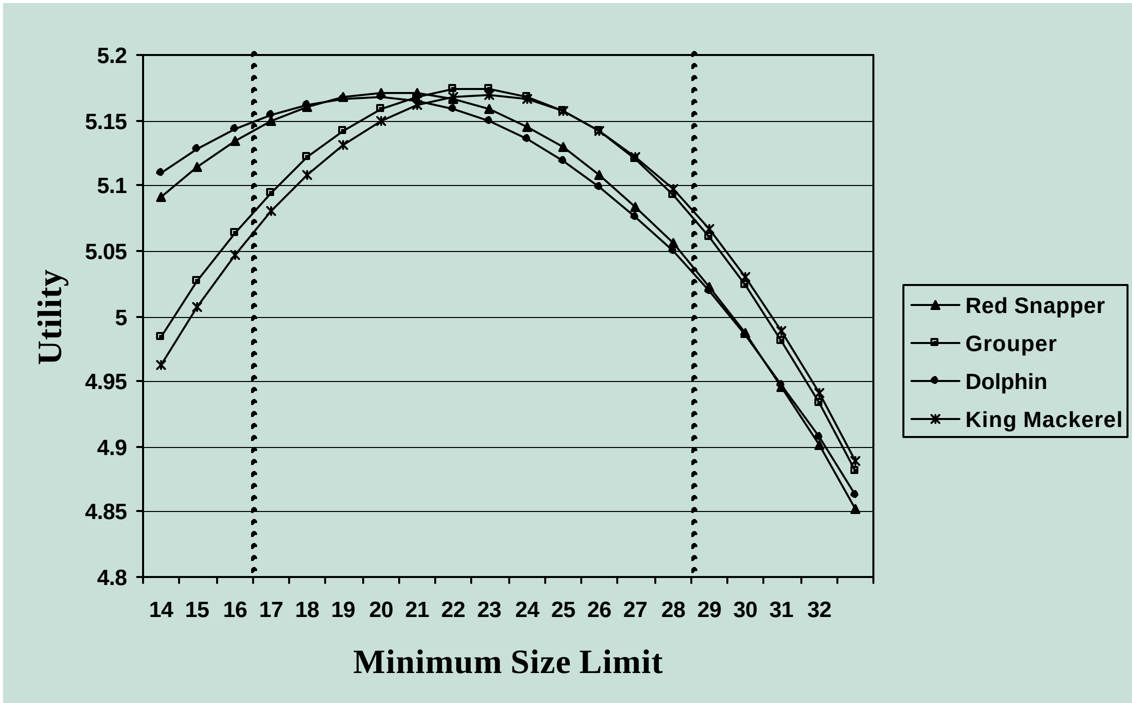



Figure 2. Utility as a function of size limit.

Tables IV and V detail the substitution elasticities for both a bag limit policy and for catch and keep respectively. The elasticities reflect the percentage change in the probability of selecting a given targeted trip relative to a one unit change in either the bag limit or the catch and keep rate. This result shows that anglers are definitely substituting away from one fishery and into another as regulations are tightened. This has implications for policy analysis. NFMS is required to examine the economic impacts of regulations and this substitution tends to dampen those impacts. Anglers are a dedicated group and unlikely to quit fishing altogether when regulations are tightened. Instead, their effort will shift to other species.

To examine changes in effort, welfare, and economic impacts across both models, a policy simulation was conducted. All four of these species were included in this SPCE because of upcoming changes in their respective management plans. Table VI details the changes in effort, welfare loss, and economic impacts stemming from a 2 fish decrease in the red snapper bag limit[b]. Bag limit was the focus here as it has the most direct connection to keep. Size limit, on the other hand, would require the incorporation of extensive size frequency data in order to simulate the effect of change size limits on catch and keep composition. The first scenario in Table VI uses the policy attribute model, first setting the current regulations across all species and then reducing the bag limit by two red snapper. Table VI indicates that this 50% reduction will reduce grouper trips by 1.05% and red snapper trips 5.18%, increase king mackerel and dolphin trips by 1.83% and 2.51% respectively, and 1.90% would not take any trip. Compensating variation per trip lost under this option is $27.99 (US dollars) and when applied to current red snapper effort yields a welfare loss of $528,759. Net effort lost under this scenario is 581 trips, and when applied to US national average trip expenditure of $49.12, as calculated from [11], there is a loss of $28,545.90 in trip expenditures[c]. Using multipliers from [12], these lost expenditures generate losses in sales impacts of $64,028.39, a $21,716.61 loss of income, and the loss of about three quarters of one full time job[d].

Table IV. Bag Limit Elasticities.

| Species Target | Bag Limit Elasticities | | | |
|---|---|---|---|---|
| | **King Mackerel** | Dolphin | Grouper | Red Snapper |
| GROUPER | 0.004 | -0.037 | 0.069 | -0.094 |
| RED SNAPPER | 0.004 | -0.037 | -0.085 | 0.101 |
| DOLPHIN | 0.004 | 0.088 | -0.085 | -0.094 |
| KING MACKEREL | -0.004 | -0.037 | -0.085 | -0.094 |

Table V. Catch and Keep Elasticities.

| Species Target | Catch and Keep Elasticities | | | |
|---|---|---|---|---|
| | King Mackerel | Dolphin | Grouper | Red Snapper |
| GROUPER | -0.123 | -0.02 | 0.114 | -0.127 |
| RED SNAPPER | -0.123 | -0.02 | -0.151 | 0.131 |
| DOLPHIN | -0.123 | 0.043 | -0.151 | -0.127 |
| KING MACKEREL | 0.102 | -0.02 | -0.151 | -0.127 |

It is much more difficult to analyze this policy change in the catch and keep model so three different approaches are used, all more illustrative than comparable to the bag limit change due to lack of information regarding how these policies impact keep. The second scenario sets keep at the current bag limit of four fish and examines the reduction to two fish. This scenario produces a total welfare loss of nearly $2.5 million. The third scenario does not fix initial conditions but allows them to vary as presented in the choice experiment and compares that to a model with keep fixed at two red snapper. This scenario produces a total welfare loss of over $1.3 million. These two scenarios were more to demonstrate the difference between using a direct policy attribute than an accurate measure of the welfare effect of these scenarios because, in reality, average catch rates for red snapper are quite low. Averaged across 10 years of MRFSS data and across all anglers catching a red snapper, the average harvest of red snapper is 0.929 fish per trip. The fourth policy scenario fixes this value as the base keep and simulates a 50% reduction is this value. Clearly this isn't correct either as the average catch and keep rate is lower than the proposed policy, further illustrating the difficulty of using a catch and keep model without more information regarding stock composition. The most correct way to simulate this policy using the catch and keep model would be to estimate some sort of count data expected catch and keep model and use the predicted values of catch and keep for each individual as the base case in the simulation. This technique is currently being pursued.

## DISCUSSION

To date, this ongoing data collection has been successful. Two models are presented here, one based on the inclusion of the policy attribute directly and the other based on catch and keep. While the policy attribute model is more expedient for policy analysis, the positive sign on the minimum size limit attribute deserves further attention. These are preliminary results based on a small fraction, less than 12%, of the data from early returns. Perhaps these coefficients will swing negative as the sample increases. Perhaps spatial or temporal factors will improve the performance of this attribute as the availability of these species varies with region and time of the

**Table VI. Effort Loss, Welfare Loss, and Economic Impacts of the 50% Reduction in the Red Snapper Bag Limit.**

| | | 1: 50% Reduction in Bag | | 2: Reduction in Keep from 4 to 2 Fish | | 3: Reduction in Keep from Sample Values to 2 Fish | | 4: 50% Reduction in MRFSS Average Keep | |
|---|---|---|---|---|---|---|---|---|---|
| Target Species | 2003 Effort | Share Change | Effort Change | Share Change | Effort Change | Share Change | Effort Change | Share Change | Effort Change |
| Grouper | 32,418 | -1.05% | -340 | 2.78% | 900 | 1.50% | 485 | 0.59% | 191 |
| Red Snapper | 18,891 | -5.18% | -979 | -11.66% | -2,203 | -5.64% | -1,066 | -2.65% | -500 |
| King Mackerel | 35,851 | 1.83% | 656 | 2.90% | 1,038 | 1.16% | 417 | 0.59% | 211 |
| Dolphin | 17,556 | 2.51% | 441 | 2.84% | 499 | 1.39% | 244 | 0.68% | 119 |
| No Trip | | 1.90% | -359 | 3.39% | -640 | 1.59% | -300 | 0.79% | -150 |
| Net Effort Loss | | | -581 | | -405 | | -220 | | -129 |
| Welfare Effects | | | | | | | | | |
| CV per Trip | | | $27.99 | | $132.28 | | $69.66 | | $25.86 |
| Welfare Loss | | $528,759 | | $2,498,901 | | $1,315,947 | | $488,521 | |
| Expenditures and Impacts | | | | | | | | | |
| Average Trip Cost | | $49.12 | | $49.12 | | $49.12 | | $49.12 | |
| Loss of Trip Expenditures | | -$28,545.90 | | -$19,898.60 | | -$10,786.37 | | -$6,345.78 | |
| Sales Impacts | | -$64,028.39 | | -$44,572.87 | | -$24,161.48 | | -$14,214.55 | |
| Income Impacts | | -$21,716.61 | | -$15,122.94 | | -$8,197.64 | | -$4,822.79 | |
| Job Losses | | -0.74 | | -0.52 | | -0.28 | | -0.16 | |

year. Regional dummies crossed with the species-specific minimum size limit attribute showed promise, but were not reported here. Additionally there is just not enough seasonal variation in this preliminary data to examine any sort of seasonal effect. Finally, further examination of the transcripts from the qualitative work may shed light on anglers' preferences for this type of regulation that may impact the way the attribute is modeled. At the very least one can model welfare effects of size limit policy using a cross of minimum size and the total keep, which is a measure of inches of fish landed as in Hicks [4].

Clearly anglers substitute into other fisheries when regulations are tightened and this paper quantifies that substitution in real terms. This substitution has the effect of softening the economic impacts by allowing some effort to shift into other fisheries. This is a far more realistic assumption than assuming that some ad hoc proportion of effort leaves fishing entirely with no considerations of angler's ability to shift their effort into other fisheries. Finally, this is only the beginning of the analysis of this data. The short list of further explorations includes the development of expected catch and keep models that incorporate size distributions and various nesting structures. Preliminary nesting was done using the stated preference for targeting and that model shows promise. Additionally the no trip option and the target species could be nested.

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## ENDNOTES

[a] These regulations are simplification of the current regulations. Currently there is no minimum size for dolphin in federal waters, but the state of Georgia has a 20-inch minimum in its state waters. Also, there are multiple species of grouper in the grouper target species group all with slightly different minimum size limits. The two most popular groupers, black and gag grouper, have a 24-inch minimum size, so that was used here.

[b] This reduction in the red snapper bag limit is strictly a creation of the author and by no means is it meant to represent an actual policy under consideration by either the South Atlantic or Gulf Fisheries Management Council.

[c] This is a simple average across resident status and trip mode including shore mode, boat mode, and the for-hire mode. The majority of red snapper trips are taken in the boat or for hire mode, which both have significantly higher trip expenditures than the shore mode. As a result this is likely a lower bound on trip costs.

[d] Economic impact multipliers were calculated at the national level, which might slightly overstate impacts over multipliers developed for the South Atlantic and Gulf Coast regions. Unfortunately, [12] did not calculate multipliers across the South Atlantic and Gulf Coast regions. US level multipliers were deemed much more suitable than state level multipliers because imports are far less a factor as geographic scope increases.

# SAM for Puerto Rico Regions—Measuring Regional Employment and Income Impacts of Market Growth and Change in Puerto Rico's Basic Industries

**Knut I. Westeren, Anwar Hussain and Wilbur R. Maki**[1]

## Introduction

The Puerto Rico development strategy is unique in many ways. In the 1960s and 1970s it came to be eulogized as the model to be adopted by other developing countries. Propped up by generous tax exemptions and subsidies to selected industries, the model has, however, been out of steam since the late 1970s. While absolute per capita has grown, relative income growth has lagged even that of Mississippi and West Virginia – two of the lowest income states in the U.S. Lacking inter-industry linkages with the rest of Puerto Rico local economy, the major beneficiary industries of subsidies and tax exemptions such as drug and pharmaceuticals could not help pull the local economy along to best utilize indigenous resources and talent.

**Table 1. Key economic indicators per worker, Puerto Rico compared with US, 1982 to 2002.**

| | | | | Total Change | |
|---|---|---|---|---|---|
| **Economic Indicator** | **1982** | **1992** | **2002** | **1982-1992** | **1992-2002** |
| | **(thou.$)** | **(thou.$)** | **(thou.$)** | **(pct.)** | **(pct.)** |
| **Puerto Rico:** | | | | | |
| **Gross National Product** | **3.8** | **6.4** | **11.1** | **67** | **73** |
| **Gross Domestic Product** | **17.6** | **24.2** | **38.6** | **38** | **59** |
| **Employee Compensation** | **23.2** | **35.4** | **60.8** | **52** | **72** |
| **Personal Income (per capita)** | **11.1** | **15.3** | **21.5** | **38** | **40** |
| **United States:** | | | | | |
| **Gross National Product** | **11.7** | **20.5** | **30.7** | **75** | **50** |
| **Gross Domestic Product** | **32.4** | **52.3** | **75.1** | **61** | **44** |
| **Employee Compensation** | **32.1** | **52.1** | **75.1** | **62** | **44** |
| **Personal Income (per capita)** | **18.8** | **30.1** | **43.3** | **60** | **44** |
| **PR as % of US:** | | | | | |
| **Gross National Product** | **54** | **46** | **51** | **-14** | **11** |
| **Gross Domestic Product** | **72** | **68** | **81** | **-6** | **19** |
| **Employee Compensation** | **59** | **51** | **50** | **-13** | **-3** |
| **Personal Income (per capita)** | **33** | **31** | **36** | **-5** | **15** |

**Puerto Rico Planning Board, Puerto Rico Economic Indicators, 1947-2002.**

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From 1982 to 2002 GNP per worker has been around 50% of the US average while GDP per worker was around 70% of the US average from 1982 to 2002 and is now about 80% of the US average (**Table 1**). Employee compensation per worker declined relative to the U.S., while personal income per capita declined from 1982 to 1992, but increased slightly from 1992 to 2002. The building up of export industries that send substantial amounts of money back to mainland USA as proprietor's income and earnings on capital investments accounted for much of the large difference between GDP per worker and GNP per worker.

## Regional structural analysis

Regional structural analysis is based on a detailed examination of the inter-industry linkages revealed from Puerto Rico's input-output tables. Findings from the 1994 study that are based on the 1982 input-output table are compared with findings from the 1992 input-output tables. We concentrate on four industries to highlight some important questions for development of the Puerto Rico economy. These industries include the Drugs and pharmaceuticals, Scientific & controlling instruments, other business services, and Visitor spending.

**Table 2** shows the economic ties between the producing sectors of the entire Puerto Rico economy and its product and labor markets. That is, it shows the aggregate of inter-industry linkages within the entire Puerto Rico economy by its industry purchases and product disbursements to other industries (intermediate demand) and sectors and to foreign markets (final demand). It also shows the contribution of each producing sector to the compensation of all primary resources--labor, capital and entrepreneurship employed by the remuneratively productive economic activity (value added). The dollar value of all disbursements of locally-produced goods and services totals to more than $37.8 billion, of which $11.9 billion went to the producing sectors and $25.9 billion represents final sales to the consuming, investing, and exporting sectors of the domestic economy.

**Table 2. Industry outlays and product disbursements, Puerto Rico, 1982.**

| | TotComm | Intermediate Demand | | Final Demand | |
|---|---|---|---|---|---|
| Sector | Production | NonGov't | Gov't | Local | ForExp |
| | (bil.$) | (bil.$) | (bil.$) | (bil.$) | (bil.$) |
| Total Input Purchases | 68.1 | 34.7 | 3.1 | 19.4 | 10.9 |
| Non-government | 34.7 | 3.6 | 0.8 | 12.0 | 10.9 |
| Government Enterprise | 3.1 | 0.1 | 0.0 | 3.0 | 0.0 |
| Subtotal | 37.8 | 11.8 | 0.8 | 15.0 | 10.9 |
| Employee Compensation | 8.9 | 6.6 | 2.2 | 0.0 | 0.0 |
| Other Value Added | 9.2 | 9.2 | 0.0 | 0.0 | 0.0 |
| Total Value added | 18.1 | 15.8 | 2.2 | 0.0 | 0.0 |
| Total Imports (non-govt) | 12.2 | 7.8 | 0.0 | 4.4 | 0.0 |

**Source: Puerto Rico IMPLAN System, 1994**

Thus, final sales of the domestic economy are more than twice the dollar value of the intermediate product sales that represent domestic inter-industry sales and purchases. Value added by the remuneratively-productive economic activity totals to nearly $18.1 billion, of which employee compensation accounts for nearly $8.9 billion, or 49 percent of the total, while indirect business taxes and gross profits, including net interest and subsidies accounted for the remaining 51 percent of total value added. Total imports were $12.2 billion, of which $7.8 billion were intermediate production inputs and $4.4 billion were final sales. These represent markets for possible import substitution programs.

**Table 3** shows the disbursement of the aggregate of industry products to their principal final markets. It includes goods and services produced locally and imported for each of the economic sectors including households (PCE), governments, business investments, and exports, largely to the U.S. The three domestic consuming sectors - of households, visitors, and government - account for $17.3 billion, or 57 percent, of the total final sales of $30.3 billion, with the personal consumption expenditures of households alone accounting for 43 percent of the total.

**Table 3. Product disbursements to final demand, Puerto Rico, 1982.**

| Sector | Total Final (bil.$) | PCE (bil.$) | Gov't. (bil.$) | Business Invest (bil.$) | Visitors (bil.$) | Foreign Exports (bil.$) | Foreign Imports (bil.$) | Net Exports (bil.$) |
|---|---|---|---|---|---|---|---|---|
| **Total Input Purchases** | **30.3** | **13.3** | **3.3** | **2.1** | **0.7** | **10.9** | **12.2** | **-1.3** |
| **Non-government** | **22.9** | **9.7** | **0.1** | **1.2** | **0.6** | **10.9** | **12.2** | **-1.3** |
| **Government Enterprise** | **3.0** | **0.2** | **2.8** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| **Subtotal** | **25.9** | **9.9** | **2.9** | **1.7** | **0.6** | **10.9** | **12.2** | **-1.3** |
| **Total Imports (non-govt)** | **4.4** | **3.4** | **0.4** | **0.4** | **0.2** | **0.0** | **0.0** | **0.0** |

**Source: Puerto Rico IMPLAN System, 1994**

The business investing sector accounted for 6.9 percent of the total while foreign exports accounted for the remaining 36 percent. Visitor spending also brings in "new dollars" into the Puerto Rico economy and thus it can be included with the foreign export sector. Together, the two account for $11.6 billion, or 38 percent, of total sales. Total foreign imports exceed total foreign exports by nearly $1.3 billion. With visitor spending included with foreign exports, the export deficit turns to a smaller export deficit of $577 million.

Government disbursements to final demand are larger for government than households. This is actually a transfer from government to industries. Total foreign imports, on the other hand, are larger for the household sector than the government sector. Foreign imports of intermediate production inputs occur only for the non-government sector. Also, foreign exports include unspecified charges that greatly increase the estimated values for manufacturing sector. A reclassification of some industry categories used in listing individual commodity exports in the merchandise accounts results in further differences in the two sets of estimates. The two sets of foreign import accounts, on the other hand, show only small differences due to inclusion of additional services and reclassification of individual commodity categories disbursements to government?

The IMPLAN-based structural analysis builds on the multiplier analysis in a series of four hypothetical impact assessments. In each case, industry exports expand by $1 million from a base year represented in **Table 4** for the seven key indicators cited earlier--final demand, total industry output, employee compensation income, property income, total place-of-work income, total value added, and total employment. These results show a larger total impact for the dominantly services type industries than the two industries with much more in the way of physical capital as revealed by the amount of property income change. The large property income component for visitor spending relates to the large share of total value added attributed to the real estate, trade, and manufacturing sectors.

**Table 4. Selected industry outlays and product disbursements, Puerto Rico, 1992.**

| Sector | Final Demand (mil.$) | Total Ind Output (mil.$) | Employee CompInc (mil.$) | Property Income (mil.$) | TotalValue Added (mil.$) | Employ-Ment (number) |
|---|---|---|---|---|---|---|
| **Drugs and pharmaceuticals** | 1.14 | 1.444 | 0.184 | 0.561 | 0.769 | 10.3 |
| **Scientific & controlling instruments** | 1.383 | 1.885 | 0.388 | 0.545 | 0.987 | 27.9 |
| **Other business services** | 1.664 | 2.142 | 0.994 | 0.383 | 1.471 | 48.4 |
| **Visitor spending** | 1.857 | 3.021 | 0.638 | 0.644 | 1.438 | 62.4 |

**Source: Maki et al. 1994**

The services-producing sectors show the larger total effects as a result of their large labor component. Increases in labor earnings convert to corresponding increases in personal consumption expenditures that account for the large induced effect. The share of property income of value added is much higher for drugs and pharmaceuticals than in the service sectors. We do not know how much of the property income that stays on Puerto Rico in the Drugs and Pharmaceuticals sector. The available evidence suggests that a substantial share of the property income in the Drugs and Pharmaceuticals sector went to U.S., while the property income in the service sector to a much higher degree remained local because of ownership structure of the businesses.

Puerto Rico industries differ sharply in their contribution to the Commonwealth's economic base as represented by its exports that bring new dollars into its economy. The Commonwealth's 1992 input-output table shows that close to 90 percent of the total production of the top six export industries was shipped out of the Commonwealth (**Tables 5, 8**). One visitor-related sector—tourists hotels—is included among the large exports-producing sectors insofar as foreign visitors bring new dollars into the Commonwealth as do exports of manufactured products. Import substitutes, on the other hand, face competition from foreign imports.

To provide a perspective on changes since 1982, Drugs and pharmaceuticals have been one major exporting sector since the build up of manufacturing in the early 1970's. This sector is the one that had the greatest advantages of the 936 IRC that are estimated to 2-3 billion dollars tax rebates yearly through the early 1990's. The sector had an industry output of $10.5 billion in 1992 of which $9.4 was exported. This is about 40% of the total export from Puerto Rico that year. In 2002 this sector exported about $21 billion which is a little more than 40% of Puerto

**Table 5. Selected industry exports and imports, Puerto Rico, 1992**

| Sector | SIC Code | Total Exports (mil.$) | Total Imports Industry (mil.$) | Total Imports Institution (mil.$) | Value Added (mil.$) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| ***Large current exports:*** | | | | | |
| **Apparel and Accessories** | **23** | **801** | **31** | **181** | **536** |
| **Drugs & Pharma Preparations** | **28** | **9,387** | **1,408** | **423** | **6,460** |
| **Electrical & Electronic Machine** | **36** | **2,968** | **1,090** | **550** | **1,289** |
| **Professional & Scientific Instruments** | **38** | **1,978** | **571** | **95** | **947** |
| **Total** | | **15,135** | **3,100** | **1,250** | **9,232** |
| ***Visitor-related:*** | | | | | |
| **Wholesale and Retail Trade** | **50-51** | **108** | **0** | **0** | **5,546** |
| **Real Estate** | **65** | **215** | **0** | **0** | **2,663** |
| **Tourists Hotels** | **pt 70** | **348** | **0** | **0** | **299** |
| **Total** | | **672** | **0** | **0** | **8,507** |
| ***Import substitutes:*** | | | | | |
| **Meat and Meat Products** | **201** | **21** | **60** | **312** | **37** |
| **Other Business Services** | **73, 87** | **0** | **108** | **0** | **1,086** |
| **Total** | | **21** | **169** | **312** | **1,123** |
| **Other industries** | | **8,058** | **9,332** | **5,180** | **18,839** |
| **Totals** | | **23,886** | **12,600** | **6,742** | **37,702** |

**Source: MIG, 1992 Puerto Rico IMPLAN-SAM database and model.**

Rico export for that year. Industry imports (mainly chemicals and semi finished goods used in production) to the drugs and pharmaceutical in 1992 was $1.4 billion while the institutional imports, mainly for consumption on the island, was $423 million. The distribution of value added for this sector is unlike the rest of the economy. Of the total value added of $6.46 billion in 1992 of the Drugs and pharmaceuticals, employee compensation was $682 million while proprietor income was $2.2 billion and property income was $3.5 billion. This demonstrates the fact that the drugs and pharmaceuticals is a capital intensive sector with high profits, but in this case the profits do not stay on the island.

**Table 6** and **9** provides some 1992 data for comparison with the base year data in **Table 4**. Employee compensation share of total value added remained relatively low in 1992 as it was in 1982. Proprietor Income and Property Income for Drugs and Pharmaceuticals remained the highest among the sectors with large current exports.

The structure of the industry is reflected in the multipliers. The output multipliers for drugs and pharmaceuticals are among the lowest for the selected industries which is what we would expect because of the high degree of imported intermediate inputs. The SAM type output is also low because the employee compensation as a part of total output is low (**Table 7**). But the differences between the output multipliers are not that big. When we come to the employment multipliers the differences become substantial. The employment multipliers are defined as number of jobs created per million dollars of output in the industry. Here the drugs and pharmaceuticals production employment multiplier is exceptionally low while the other capital intensive export oriented industries have on the average twice as high multiplier. The largest difference is between tourist hotels having an employment multiplier more than six times as large as drugs and pharmaceuticals. Bottled and canned soft drinks was an important export industry in 1992 and has in 2002 an export of $2.6 billion which in fixed prices is about the same volume as in 1992. The industry makes semi finished products for manufacturing beverages. This is also a capital intensive and high profit industry but differs from drugs and pharmaceuticals by being a low wage industry.

**Table 6. Selected industry value added and employment, Puerto Rico, 1992.**

| Sector | SIC Code | Value Added (mil.$) | Emp Comp (mil.$) | Proprietor Income (mil.$) | Property Income (mil.$) | Indirect BusTax (mil.$) | Employ-ment (number) |
|---|---|---|---|---|---|---|---|
| *Large current exports:* | | | | | | | |
| Apparel and Accessories | 23 | 536 | 344 | 64 | 101 | 28 | 12.6 |
| Drugs and Pharmaceutical Prepara | 28 | 6,460 | 682 | 2,228 | 3,526 | 24 | 18.9 |
| Electrical and Electronic Machine | 36 | 1,289 | 372 | 342 | 541 | 34 | 16.9 |
| Professional and Scientific Instru | 38 | 947 | 299 | 247 | 391 | 10 | 8.9 |
| Total | | 9,232 | 1,697 | 2,880 | 4,559 | 96 | 57.3 |
| *Visitor-related:* | | | | | | | |
| Wholesale and Retail trade | 50-51 | 5,546 | 2,104 | 879 | 1,391 | 1,172 | 152.6 |
| Real Estate | 65 | 2,663 | 203 | 933 | 1,476 | 50 | 6.4 |
| Tourists Hotels | pt 70 | 299 | 203 | 23 | 37 | 36 | 10.8 |
| Total | | 8,507 | 2,510 | 1,835 | 2,904 | 1,258 | 169.8 |
| *Import Substitutes:* | | | | | | | |
| Meat and Meat Products | 201 | 37 | 27 | 3 | 5 | 1 | 2.7 |
| Other Business Services | 73, 87 | 1,086 | 417 | 257 | 407 | 5 | 37.5 |
| Total | | 1,123 | 444 | 260 | 412 | 6 | 40.2 |
| Other industries | | 18,839 | 10,276 | 3,008 | 4,761 | 795 | 576.6 |
| Totals | | 37,702 | 14,927 | 7,983 | 12,636 | 2,155 | 843.9 |

**Source: Minnesota IMPLAN Group, Inc., Puerto Rico IMPLAN-SAM Model, 2004.**

Each of the multiplier series is weighted by the importance of the multiplier component in produced one unit of industry output. The larger the foreign exports, the smaller the indirect effect, that is, the measure of backward linkages of the given industry. The indirect effect measures of the backward linkages to local input sources. The large induced effects account for the large total multipliers for the high value-added export-producing industries.

**Table 7. Selected industry output and employment multipliers, Puerto Rico, 1982 and 1992**

| | | Output | | | | Employment | |
|---|---|---|---|---|---|---|---|
| | | Type 1 | | SAM-type | | Type 1 | SAM-type |
| Sector | SIC Code | 1982 | 1992 | 1982 | 1992 | 1992 | 1992 |
| *Large current exports:* | | | | | | | |
| Apparel and Accessories | 23 | 1.2 | 1.2 | 2.6 | 1.8 | 14 | 24 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Drugs and Pharmaceutical Preparations** | **28** | **1.2** | **1.3** | **1.4** | **1.9** | **4** | **14** |
| **Electrical and Electronic Machinery** | **36** | **1.4** | **1.4** | **1.9** | **2.0** | **10** | **19** |
| **Professional and Scientific Instruments** | **38** | **1.3** | **1.4** | **1.9** | **2.0** | **8** | **18** |
| ***Visitor-related:*** | | | | | | | |
| **Wholesale and Retail Trade** | **50-51** | **1.4** | **1.4** | **3.0** | **2.4** | **22** | **41** |
| **Real Estate** | **65** | **1.6** | **1.6** | **1.9** | **2.3** | **8** | **20** |
| **Tourists Hotels** | **pt 70** | **2.0** | **1.5** | **3.9** | **2.4** | **28** | **46** |
| ***Import substitutes:*** | | | | | | | |
| **Meat and Meat Products** | **201** | **2.7** | **1.9** | **4.1** | **2.6** | **26** | **37** |
| **Other Business Services** | **73, 87** | **1.1** | **1.3** | **2.1** | **2.1** | **31** | **44** |

**Source: Minnesota IMPLAN Group, Inc., Puerto Rico IMPLAN-SAM Model, 2004.**

Low indirect effects are measures of the potential for import replacement as exports expand. At some point, the economies of scale will be such that a local input-supplying industry can emerge to replace the heretofore imported production inputs. High indirect effects, on the other hand, denote strong linkages to local input suppliers. Low induced effects result from low levels of value added and place-of-work income generated per unit of industry output. However, many of the export-producing industry generate high levels of value added and place-of-work income and, consequently, their induced effects are large. Thus, the demand multipliers for the export-producing industries are generally above-average in value.

## Using IMPLAN to analyze development possibilities

Two studies using IMPLAN for Puerto Rico were completed over the past decade. These include Maki et al. (1994) that used 1982 as the base year, and the new version of IMPLAN for Puerto Rico constructed in 2002. In this article we will mainly use the 1992 version and compare, in part, with aggregate results for 1982. Table 1, presented earlier, lists the rates of change in the individual key economic indicators. These range from the large annual increases in visitors and visitor spending and foreign trade to the large annual decline in the unemployed labor force. All are measures of an expanding economy. Meanwhile, the growth in total population dropped from one percent per annum in the period 1982-87 to 0.9 percent in the period 1982-87 and 0.8 percent in the 1990-91period. The total labor force, on the other hand, grew rapidly. Note the emergence of workers from informal economy into formal economy. The employed workforce grew even faster, which thus reduced the unemployed labor force from 199 thousand in 1982 to 167 thousand in 1992 **(**Table 8**).**

### Export expansion scenarios

While scenarios such as reducing subsidies and observing the response of industry versus institutional sectors, and the pattern of inter-regional trade are important, policy questions arising from the Puerto Rico IMPLAN study fall largely under the "export expansion" umbrella. Exports, whether domestic or foreign, are those goods and services that are produced locally that generate income flows from the outside to area residents. This policy issue, of course, is not simply a declaration of intent to expand exports, but a real effort to provide the underpinnings of successful export expansion on the part of the export-producing sector of the Puerto Rico economy. This sector includes all activities engaged in producing goods and services purchased by non-residents that generate income payments to the residents of the area. The area, in every case, is the local labor market area.

**Table 8. Total industry exports and imports share of total output, Puerto Rico, 1992**

| | | | Total Imports | | VA Share | EmpCom |
|---|---|---|---|---|---|---|
| | SIC Code | Exports | Industry | Institutions | of Output | Share VA |
| | | (pct.) | (pct.) | (pct.) | (pct.) | (pct.) |
| *Large current exports:* | | | | | | |
| Apparel and Accessories | 23 | 70 | 3 | 16 | 47 | 64 |
| Drugs & Pharma Preparations | 28 | 90 | 13 | 4 | 62 | 11 |
| Electrical & Electronic Machine | 36 | 87 | 32 | 16 | 38 | 29 |
| Professional & Scientific Instruments | 38 | 96 | 28 | 5 | 46 | 32 |
| Total | | 89 | 18 | 7 | 54 | 18 |
| *Visitor-related:* | | | | | | |
| Wholesale and Retail Trade | 50-51 | 1 | 0 | 0 | 61 | 38 |
| Real Estate | 65 | 5 | 0 | 0 | 59 | 8 |
| Tourists Hotels | pt 70 | 71 | 0 | 0 | 61 | 68 |
| Total | | 5 | 0 | 0 | 60 | 30 |
| *Import substitutes:* | | | | | | |
| Meat and Meat Products | 201 | 8 | 23 | 118 | 14 | 73 |
| Other Business Services | 73, 87 | 0 | 8 | 0 | 77 | 38 |
| Total | | 1 | 10 | 19 | 67 | 40 |
| Other industries | | 21 | 24 | 13 | 48 | 55 |
| Totals | | 33 | 17 | 9 | 52 | 40 |

**Source: MIG, 1992 Puerto Rico IMPLAN-SAM database and model.**

Manufacturing shows the largest number of declining industries, specifically, apparel and other textile products, electric and electronic equipment, and instruments and related products. With one exception, the services-producing industries accounted for more jobs and a larger share of total jobs in 1992 than in 1982. The largest relative growth occurred in business services. Retail trade accounted for the largest absolute increase during this period.

## Market competitiveness scenarios

The Puerto Rico IMPLAN model and database provides the policy analyst with two types of results: those from its multiplier analysis and those from its structural analysis. The multiplier analysis can show the industry-specific, as well as economy-wide, effects of changes in any export-producing activity or activity cluster. The structural analysis on the other hand not only show the multiplier effects but the entire set of inter-industry and inter-sectoral relationships that help identify important limits as well as possibilities for Puerto Rico's economic growth and development in the years ahead.

**Table 9. Selected industry output and value added per worker, Puerto Rico, 1992**

| | Industry | Value | Emp | Proprietor | Property | Indirect |
|---|---|---|---|---|---|---|

| Sector | SIC Code | Output (thou.$) | Added (thou.$) | Comp (thou.$) | Income (thou.$) | Income (thou.$) | BusTax (thou.$) |
|---|---|---|---|---|---|---|---|
| *Large current exports:* | | | | | | | |
| Apparel and Accessories | 23 | 91 | 43 | 27 | 5 | 8 | 2.2 |
| Drugs and Pharmaceutical Prepara | 28 | 554 | 342 | 36 | 118 | 187 | 1.3 |
| Electrical and Electronic Machine | 36 | 202 | 76 | 22 | 20 | 32 | 2.0 |
| Professional and Scientific Instru | 38 | 231 | 107 | 34 | 28 | 44 | 1.1 |
| Total | | 298 | 161 | 30 | 50 | 80 | 1.7 |
| *Visitor-related:* | | | | | | | |
| Wholesale and Retail trade | 50-51 | 60 | 36 | 14 | 6 | 9 | 7.7 |
| Real Estate | 65 | 704 | 414 | 32 | 145 | 230 | 7.8 |
| Tourists Hotels | pt 70 | 45 | 28 | 19 | 2 | 3 | 3.3 |
| Total | | 83 | 50 | 15 | 11 | 17 | 7.4 |
| *Import Substitutes:* | | | | | | | |
| Meat and Meat Products | 201 | 99 | 14 | 10 | 1 | 2 | 0.5 |
| Other Business Services | 73, 87 | 37 | 29 | 11 | 7 | 11 | 0.1 |
| Total | | 42 | 28 | 11 | 6 | 10 | 0.2 |
| Other industries | | 68 | 33 | 18 | 5 | 8 | 1.4 |
| Totals | | 85 | 45 | 18 | 9 | 15 | 2.6 |

**Source: MIG, 1992 Puerto Rico IMPLAN-SAM database and model.**

The growing diversity and strength of the Puerto Rico economy stems, in part, from its expanding trade with the U.S., Mexico, and other countries. However, for the individual labor markets of Puerto Rico, defined by the journey to work of the local labor force, inter-area trade gradually becomes an equally, if not more important, source of local economic growth and change as incomes rise and means of domestic transportation and communication improve. The founding of new businesses and the expansion and contraction of existing ones brings about a diversity of products that initially find a local market niche. If successful, their products reach nearby and eventually more distant markets until the domestic economy becomes one large product market.

Producers in each labor market area assert some competitive advantage in producing goods and services for local and area markets. Superior access to markets, coupled with the rising worker incomes, increasing productivity of the local workforce, and increasingly competitive business enterprise, account for the expanding domestic trade.

## Summary and Conclusions

Based on an analysis of the Puerto Rico IMPLAN input-output accounts it emerges that in future Puerto Rico development strategy would need to target industries with strong local backward and forward linkages and those that would ensure higher wages and employee compensation for local residents. Reliance on capital intensive industries in the past has only engendered income inequalities and dependence on un-earned income from the U.S. and Puerto Rico government.

**Puerto Rico economy a demonstration case:** The Puerto Rican growth model has come to fascinate many for its unusual turns. Despite increases in absolute per capita, unemployment rates have lately been the highest since great depression; the allure of tax exemptions and subsidies have resulted in a economic state where most of the value added leaves the Island; increases in per capita are not the results of development but accrue due to remittances sent by about 1 million Puerto Ricans home, federal payments of un-earned incomes; an economic performance that is not consistent with local material and human resources.

**Industries with promise for development:** Future development strategies may need to focus on services-producing sectors, exploit local human capital and rely on a growth pattern characterized by strong backward and forward inter-industry linkages. The services-producing sectors show the larger total effects as a result of their large labor component. Increases in labor earnings convert to corresponding increases in personal consumption expenditures that account for the large induced effect. The share of property income of value added is much higher for drugs and pharmaceuticals than in the service sectors. We do not know, however, how much of the property income earnings stay in Puerto Rico. The IMPLAN findings, as well as the large difference between GNP and GDP, point to a large share of these earnings leaving the Commonwealth.

**Regionalization of databases for future analysis:** To effectively plan and monitor the prospects for growth and development, it is important to assess potential at regional level. Among other factors, however, it would require building regional input-output models on a pattern similar to IMPLAN models for U.S. counties and individual states.

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# How Does Highway Infrastructure Investment Affect Oklahoma's Economic Development: A Computable General Equilibrium Model

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## 1. Introduction

One third of the nation's infrastructure is provided by the public, and highway construction and maintenance dominate transport infrastructure spending. Public infrastructure would include government spending on sewer and waste, transportation facilities and services, education, and water services. Private infrastructure might include services such as banking, finance, management and accounting services (Maki and Lichty). Literature on public infrastructure investment to this point has primarily focused on its productivity, measured by growth in income, employment, and output (Babcock, Emerson, and Prater). While improvements may make a region more attractive to industry, they may also make transport easier, lessening the need for firms to move (Kilkenny). Some discrepancy exists as to whether increased infrastructure investment hinders or helps economic development (Vickerman, Spiekermann, and Wegener).

The purpose of this research is to determine how gross state product and other measures of welfare change when public investment in highway infrastructure is increased. Policymakers need to know how improvements in the road system affect the economy. This leads to the ultimate research question: how do improvements in road infrastructure affect regional economic development? Answering this question could provide policymakers with better information for deciding whether to improve the road system.

While a variety of models have examined the effects of transportation infrastructure, a regional computable general equilibrium (RCGE) model will give the best picture of all markets, from factor resources (including migration) to commodities (including trade). Results may also be used to trace distribution effects from economic sectors to households. This picture could then be used to estimate returns to private investment from decreased transport cost, which might be a better determination of what attracts private industry to a region. In addition, the RCGE model will examine the effect of an increase in the level of public investment in highway infrastructure through an exogenously introduced change.

CGE modeling also has advantages over partial equilibrium and input-output modeling. These functions of CGE modeling make it an asset to this research. In a partial equilibrium study, one good's price is examined while the prices of all other goods are treated as fixed. Partial equilibrium only examines one market. However, a change in one market may affect other markets in an economy. General equilibrium analysis captures these effects by representing an economy as a set of equations, thereby examining effects of a change on all the markets in an economy (Nicholson). Regional CGE models differ from input-output models because the

RCGE models are guided by neoclassical theory. They show the complete circular flow of income and expenditures in a region by including household, government, and industrial sectors, whereas I/O models mostly focus on the intermediate flows between industrial sectors (Partridge and Rickman). In RCGE, factor demands depend on output and relative factor prices rather than depending linearly on output.

## 2. Theory

An exogenous shock of increased public investment in highway infrastructure lowers the cost of transportation in the region. Once the exogenous change is made, the system of equations is solved for the new equilibrium. Assuming that public infrastructure investment substitutes for private investment in transportation services, the lowered transport cost attracts firms to a region, and they increase the demand for local resources. The new equilibrium solution provides the increased levels of output, employment, household income and factor prices (rental rates of private capital). The difference between the new equilibrium solutions and the benchmark equilibrium solutions represent the effects of the increase in public investment.

A general equilibrium solution requires that several conditions be met. Consumers maximize utility subject to a budget constraint of initial commodity endowments and producers maximize profits. All demand functions must be homogeneous of degree zero in prices, meaning that if all prices (including wages) double, then the quantity demanded of each good remains the same. All demand functions must also be continuous, implying that if prices change by a small amount then the quantity demanded also changes by a small amount. Finally, at the equilibrium set of prices, excess demand equals zero in all markets; this stems from Walras' law that the total value of excess demand at any set of prices equals zero (Nicholson). Assumptions include perfectly competitive factor markets and price-responsive factor demands. Also, households maximize utility when making consumption decisions, responding to price differences among goods and services (Partridge and Rickman).

The model incorporates some structural features from Robinson, Kilkenny, and Hanson. Their national model focuses on international trade issues, incorporating imperfect substitution between demand for imported and domestic goods, and includes a parallel treatment of export supply, incorporating imperfect transformability between production for foreign markets and domestic markets at the sector level. The model, with the above treatment of exports and imports, insulates the domestic price system from changes in world prices of sector substitutes and also assumes that the U.S. cannot affect the world prices of goods and services it imports (the "small country" assumption). The model also assumes downward sloping world demand for some U.S. agricultural commodities, with all other exports having fixed world prices. Each sector produces a composite commodity that can be sold in domestic markets or transformed to the export market, and each industry produces output according to a production function that uses primary and intermediate inputs. Government spending is considered exogenously. A social accounting matrix (SAM) depicts the economy at a point in time, showing the transactions of the CGE model's economy (Robinson, Kilkenny, and Hanson).

Schreiner et al gives a procedure for constructing a SAM at the state and regional levels. SAMs capture the circular flow of goods and services from firms to households and the factor market flows from households to firms. With SAM accounts constructed to balance inputs and outputs, the row and column totals in a social accounting matrix are equal, and so they represent a regional economy in equilibrium. The type of data included in a SAM depends on the region in question and the type of questions being studied. As an illustration, the authors construct a simplified SAM for the state of Oklahoma (Schreiner et al).

Robinson, Kilkenny, and Hanson outline a procedure for calibrating the model. A base year, or benchmark year, SAM must be constructed. The authors state that common calibrating practice assumes that the chosen base year for the model also serves as the base year for price indices. Prices are then normalized to one, and thus the SAM's sectoral flows measure real as well as nominal magnitudes. Solving the model's equations in reverse, parameters are derived from the equations given the base year variable values. If the model is working properly, the base year SAM values will be reproduced (Robinson, Kilkenny, and Hanson).

Regional economies have greater openness than national economies, complicating regional CGE modeling (Partridge and Rickman). Regions trade with foreign countries as well as other regions, and labor moves more easily between regions than between countries. Savings of regional residents have less influence on regional investments, creating a divergence between the place of factor employment and place of factor income expenditure. Interaction between regional and federal government levels with regard to expenditure, tax and transfer policies are further nuances. Some regional CGE models try to incorporate these elements, and other models simply ignore the greater openness of regional economies and follow the national CGE model framework (Partridge and Rickman).

Because regional CGE models usually include intermediate inputs, a nesting procedure allows for intermediate goods to be treated differently than value added factors. At the lowest level of this nest, intermediate inputs can either be imported or purchased domestically. RCGE modeling makes use of the classic Armington assumption, that goods produced in different regions are imperfect substitutes and usually specified by a constant-elasticities-of-substitution (CES) function. These intermediate goods combine to form composite intermediate goods for the next level of production. Reinert and Roland-Holst use econometric methods to estimate Armington elasticities for mining and manufacturing sectors of the U.S. economy. Using government sources for their data, the authors found statistically significant CES elasticities for most of the mining and manufacturing sectors. Partridge and Rickman give an advantage of RCGE modeling with regard to transportation; RCGE incorporates transportation costs and production costs into the determination of regional location of economic activity.

Partridge and Rickman list some potential problems and further areas of research concerning regional computable general equilibrium modeling. RCGE models are frequently criticized for using Cobb-Douglas and CES functional forms, seen as too restrictive and arbitrarily imposed on the economy. Alternatives to the Cobb-Douglas and CES functions include flexible functional forms such as the Translog and Generalized Leontief. Much criticism and debate stems from the calibration procedure. Some critics say that relying on one benchmark year underidentifies the system, with too much reliance on external sources for elasticities and other parameters. Problems arise if elasticities in the literature were estimated with procedures inconsistent with the CGE model in which they will be used. Final problems concerning CGE modeling include the scarcity of regional data and structural features of the model that tend to be based more on convenience than knowledge of the region in question (Partridge and Rickman).

# 3. The Oklahoma CGE Model

Based on Schreiner et al's 1993 Oklahoma CGE model, this model includes four sectors: agriculture, mining, manufacturing and services. The model contains one aggregate household and one aggregate government sector. While the Schreiner model represents a static solution for one year, the inclusion of a time dimension converts it to a dynamic model. The model has a baseline, benchmark year, and then a one-time shock of public highway capital and its effects during a twenty year period are examined.

Households consume regional commodities in two levels (Schreiner et al). First, they maximize utility from leisure and consumption of a composite commodity subject to work and leisure time, budget constraints and prices. Second, they choose an optimal combination of imported and locally produced commodities. The level of demand for local and imported goods depends on the minimum cost combination of the two. The first level (1) derives from a Linear Expenditure System (LES), and the second level (2) is modeled by a Constant Elasticity of Substitution (CES) function.

$$(1)\quad Q_{ih} = \mathrm{B}_{ih} \frac{HE_h}{P_i}$$

$$(2)\quad Q_{ih} = f_i^Q \left[ d_i^Q QM_{ih}^{r_i^Q} + (1 - d_i^Q) QR_{ih}^{r_i^Q} \right]^{\frac{1}{r_i^Q}}$$

In (1) $\mathrm{B}_{ih}$ is the marginal budget share, $P_i$ is the price of commodity $i$, and $HE_h$ represents household expenditures. $Q_{ih}$ represents household demand for the commodity. In (2), $f_i^Q$ is the household consumption efficiency parameter, $d_i^Q$ is the share parameter, and $QM_{ih}$ and $QR_{ih}$ represent household demand for imported and regionally produced goods, respectively. The substitution parameter, $r_i^Q$, is calculated as follows:

$$(2a)\quad r_i^Q = \frac{s_i^Q - 1}{s_i^Q}$$

where $s_i^Q$ represents the elasticity of substitution between goods.

The government and capital formation sectors face a CES function for commodity demand similar to that of households. As with household demand, imported and regionally produced commodities are imperfect substitutes (Schreiner et al).

On the production side, the model follows Schreiner et al, but also incorporates the public highway capital as an input in production, following Seung and Kraybill. For each of the industrial sectors (agriculture, mining, manufacturing and services), a Cobb-Douglas (CD) function represents substitution among the primary factors of production (land, labor, capital). The services sector adds the public capital input to the production function. The assumes that the public highway capital input reduces costs in the transportation services sector; the effect of that reduced cost reflects in the input decisions of firms in the other sectors of the economy.

$$(3)\quad VA_i = f_i^{VA} LAB_i^{a_i^L} CAP_i^{a_i^K} LAND_i^{a_i^T} G^{a_g}$$

$VA_i$ represents composite factor value added, $f_i^{VA}$ is the factor efficiency parameter, and *LAB*, *CAP*, *LAND* represent labor, private capital, and land inputs for industry *i*, respectively. *G* represents the public capital input. The $a$ s represent production elasticities for each industry. The model assumes constant returns to scale among the primary inputs by imposing the restriction that the production elasticities on each input sum to one. The public capital input, as an unpaid factor of production, is assigned the elasticity of 0.855, estimated in Lusby. The factor elasticities on the primary inputs become the factor shares, calibrated by the model.

Each industry also has a choice whether to export their commodity or sell it in the regional market. CGE analysis assumes exports and regionally sold products are differentiated by market, and a constant elasticity of transformation (CET) function represents the relationship between them (Schreiner et al).

$$(4)\quad X_i = f_i^X \left[ d_i^X EXP_i^{r_i^X} + \left(1 - d_i^X\right) R_i^{r_i^X} \right]^{\frac{1}{r_i^X}}$$

$$(4a)\quad r_i^X = \frac{s_i^X + 1}{s_i^X}$$

In (4), $X_i$ represents total output for each industry, $f_i^X$ represents the output efficiency parameter, and $d_i^X$ is the share parameter. $EXP_i$ and $R_i$ represent sector supply for export and for regional markets, respectively. The symbol $s_i^X$ represents the elasticity of transformation for each industry with $r_i^X$ in (4a) being the output substitution parameter. Each firm allocates output between the region and export markets so as to maximize revenue subject to the CET function (Schreiner et al).

The public capital input consists of government expenditures on highway infrastructure. Public capital is accumulated as follows, adapted from Seung and Kraybill:

$$(5)\quad G_t = (1 - d)G_{t-1}$$

In year *t*, the level of public capital equals the amount of public capital in the previous year minus the amount of capital depreciated during the course of the year. The parameter *d* represents the depreciation rate, taken as equal to 0.03 from Garcia-Mila and McGuire. The model assumes a one time public capital expenditure in year one, and the amount of that expenditure depreciates in each successive year.

In year zero, the benchmark year, the effect of public capital expenditure is assumed to be reflected in the efficiency parameter. $G_t$ is the increase in public capital above the benchmark year. To offset the increase in government expenditure, a tax is added to the model, in addition to the taxes paid by both households and firms. The additional tax is equal to the total additional highway capital expenditure divided by the twenty-year lifetime of the investment, compounded at 0.03% interest. The amount of highway capital expenditure is based on the public highway capital stock data series created in chapter two. The change in the level of public highway capital stock in Oklahoma from 1999 to 2000 equals $637 million dollars. Assuming the government chooses to increase its public highway capital expenditure by ten percent, the increase in expenditure equals $63.7 million dollars. Dividing that number by twenty results in the annual value of $3.185 million, compounded in (6).

$$(6)\quad 3.185(1+0.03)^{t}$$

In (6), $t$ represents the year. The tax level, from (6), in each year is subtracted from household income.

The model assumes mobile private capital and mobile labor. Labor and private capital migration happens when prices between the region and the rest of the world differ. The Schreiner et al model employs functions that model the migration of labor and private capital.

$$(7)\quad LMIG = LS0 * e^{L} * \log\left(\frac{P_L}{P_{LE}}\right)$$

$$(8)\quad KMIG = \sum_{i=1}^{n} KS0_i * e^{K} * \log\left(\frac{P_K}{P_{KE}}\right)$$

In (7), *LMIG* represents labor migration, while *LS0* represents initial labor supply. $P_L$ and $P_{LE}$ represent local labor wage and rest-of-world labor wage, respectively. The nomenclature is similar for (8), with labels for private capital and private capital prices. The $e$ symbols represent the labor and private capital migration elasticities, which must come from the literature.

To simulate dynamics, the model sequences static equilibria through time, producing changes in stocks of labor, private capital, and public capital through migration of labor and private capital, and depreciation of the public highway capital stock (Seung and Kraybill). From the base year, the highway capital increases the government expenditures and the model is run, generating a new equilibrium. The new equilibrium, with its changes in labor and capital stocks, then has a new depreciated level of public capital introduced, producing the next equilibrium solution. This sequencing continues for twenty years, which Fraumeni assumes to be the service life of pavement on highways. The changes in labor, private capital, gross regional product, and household and enterprise income represent the effects of the initial investment in highway capital.

## 4. Data

Schreiner et al construct a benchmark data set using a social accounting matrix (SAM) from the Minnesota IMPLAN Group (MIG). MIG created the Oklahoma SAM using secondary data from BEA REIS, BLS ES202 and several other sources. The SAM incorporates national income and product accounts, household transfer payments and distributions from the Census of Population, BEA REIS and BLS Consumer Expenditure Survey, plus government data from the Annual Survey of State and Local Government Expenditures (Schreiner et al). This model uses the Schreiner et al SAM for the benchmark year.

The public highway capital expenditure is calculated in a manner following Seung and Kraybill. For their study, they implemented public capital expenditures by calculating public capital as a percentage of benchmark year GRP. For the Oklahoma model, the public highway capital level is calculated as ten percent of the increase in the total public highway capital stock level for Oklahoma from 1999 to 2000 (Lusby).

Certain parameters in the algebraic equations of the model must be calibrated, such as the efficiency parameter in (3). The calibration process determines the values for these parameters by using the data on exogenous and endogenous variables in the benchmark equilibrium. The calibration process replicates the SAM's flow values and determines the values of the parameters.

Only relative prices matter in CGE analysis, so all prices and factor rents are normalized to unity for the benchmark equilibrium. Normalizing prices to one allows the flow values in the SAM to be interpreted as physical quantity indexes for the commodity and factor markets. With the calibrated parameters attached to the equations in the CGE model, the benchmark equilibrium flows should be replicated.

Because the model uses flexible functional forms such as the CET and CES functions, the calibration process must be supplemented by parameters obtained from economic literature. These parameters include migration elasticities for private capital and labor and price elasticities of export demand (Plaut, Schreiner et al, Lusby). Table 1 displays a list of elasticities for this model.

## 5. Results

The simulation is carried out over a period of twenty years, representing the service life of the new pavement installed with the additional highway capital expenditure. The benchmark year serves as a baseline, assuming that the equilibrium solution in the benchmark year would remain unchanged without the increase in government expenditures. The simulation introduces the highway capital in year one, and every year after that the capital depreciates at a rate of 0.03 percent per year, assuming no new public highway capital outlays in each successive year.

Table 2 best shows the effects of the public highway capital investment, given by changes in private capital income, gross regional product, household disposable income, and adjusted labor income. For each year, the data are indexed to the benchmark year, as a percentage of benchmark year levels. For example, the level of gross regional product in year twenty is divided by the level of gross regional product in year zero (the benchmark year), resulting in an index number of 0.9985, meaning that in year twenty, gross regional product is at 99.85 percent of its benchmark level. Figure 1 shows the results graphically.

Private capital income rises above benchmark year levels in year one and remains above benchmark levels out to year twenty, where it stays at approximately 1.001. Gross regional product rises above 1.00 in year one then falls to just above 0.998 in year twenty. Disposable household income and labor income show the greatest improvement over the service life of the increased highway capital, rising above 1.001 by the end of the simulation.

Table 3 displays the effects of the public highway capital on capital and labor migration into and out of the region. In year one, both private capital and labor experience in-migration into Oklahoma. In subsequent years, labor migration stays at near zero levels, while private capital experiences out-migration. Beginning in year sixteen, both labor and private capital show a rise in in-migration until year twenty. Both capital and labor migration show a downward trend as the end of the simulation approaches, but, on net, the region received a growth in workers and in private capital by the end of the simulation. Figure 2 graphically shows the year by year changes in migration of private capital and labor.

Figures 3 through 6 show the effects of public capital on production in each of the four sectors, relative to the base year levels. In Figure 3, agriculture shows an increase in imports and exports until year two, while regional production falls below initial levels. Imports and regional production follow the same pattern, staying below initial levels but increasing throughout the twenty year period. Exports climb back above initial levels in year eight then fall below the benchmark level in year thirteen. In Figure 4, the mining sector experiences a rise in exports from year three to year eight, when exports fall below the benchmark level. Imports and regional production fall below benchmark levels and remain there throughout the study. In Figure 5, the manufacturing sector shows an increase in exports through year two, a dip in exports until year twelve, then a rise in exports until the end of the study. Imports and regional production fall just below benchmark levels and remain there. In Figure 6, the services sector shows a brief rise in imports in the first few years then a general downward trend in imports, exports and regional production.

Table 3 shows the effects of public capital on prices in the region, including the labor wage, the land rent, private capital rents and the prices faced by consumers and producers in the state. In the case of services, prices rose above 1.00 which may have led to the decline in production in that sector. In the mining and manufacturing sectors, exports rose when prices fell below 1.00 and fell when prices returned to 1.00 or rose higher than 1.00. The prices in the agriculture sector in Table 3 maintain at 1.00, even though the production in the agriculture sector fluctuates in Figure 3. At three decimal places, the changes in agriculture prices were probably too small to appear in the table. The price increase in the services sector seems to contradict the assumption that the public capital would reduce costs in the transportation sector; this may be due to the high aggregation of the services sector. The public capital input only applies to the transportation services sector but by default applies to all industries in the services sector in this model.

## 6. Summary and Conclusions

The CGE model constructed here is a dynamic model examining the effects of an investment in public highway capital over a period of twenty years. The public capital depreciates at 0.03 percent per year. A tax on households offsets the extra government expenditures. Over the course of the twenty years, gross regional product initially rises above then falls below benchmark level. However, labor income, private capital income, and disposable household income rise above benchmark levels. Labor and private capital migration fluctuate during the period in sync with changes in the wage rate and private capital price, and, when summed over the twenty-year period, results indicate a net gain for the state in terms of labor migration and private capital migration. These changes are relatively small (less than one percent), which may be due in part to the relatively small increase highway infrastructure spending; however, the small changes may also indicate that public capital spending has a smaller role in Oklahoma's economy than hypothesized.

Some issues with the model should be resolved in further research. Private capital should be subject to a depreciation scheme to more accurately reflect producers' choices regarding that input in future years. As well, Schreiner et al say that the household consumption function derived from the LES is not appropriate for dynamic analysis. Seung and Kraybill used a CES function for a representative consumer, and such a function might be appropriate here; of course, a CES function would require an elasticity parameter from the literature. As well, the formulation of the services sector assumes that all industries in the services sector receive the public capital input. It would be beneficial to disaggregate the services sector so that only the transportation services sector receives the public capital input. Finally, a steady-state growth path should be established for the economy in labor, private capital and public capital, so that all three grow at the same rate. A sequence of equilibria without the capital increase could then be compared with the sequence that includes the capital increase for more accurate policy impacts (Seung and Kraybill).

The early gains in labor and capital migration, plus an early GRP gain, seem to indicate that a continuous investment in public highway capital would be beneficial to the state. Further experiments would include an additional government investment in highway capital each year, added to the leftover effect of the public capital from the previous year. Another appropriate experiment would examine any possible utility effects for individuals resulting from the highway capital investment. For example, a smoother ride to work affects an individual's welfare, though such an effect is difficult to quantify. While this model leaves room for improvement, it does show that investing in public highway capital can have a positive effect on portions of the economy.

Table 1. Elasticities for the Oklahoma CGE Model

| | |
|---|---|
| Elasticities of Commodity and Intermediate Input Import Substitution[a] | |
| Agriculture | 1.47 |
| Mining | 1.84 |
| Manufacturing | 1.75 |
| Services | 0.60 |
| Elasticities of Transformation[b] | |
| Agriculture | 3.90 |
| Mining | 2.90 |
| Manufacturing | 2.90 |
| Services | 0.70 |
| Elasticities of Migration[c] | |
| Private Capital Migration | 0.92 |
| Labor Migration | 0.92 |
| Elasticity of Output for Transportation Infrastructure[d] | 0.855 |

[a]From Bilgic, King, Lusby, and Schreiner.

[b]From Schreiner et al.

[c]From Plaut.

[d]Estimated in chapter two.

Table 2. Effects on Income and Gross Regional Product Relative to Base Year

| Year | KY | GRP | DYH | ALY |
|---|---|---|---|---|
| 0 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 1 | 1.0004 | 1.0007 | 1.0007 | 1.0010 |
| 2 | 1.0004 | 1.0004 | 1.0006 | 1.0010 |
| 3 | 1.0006 | 1.0003 | 1.0007 | 1.0010 |
| 4 | 1.0006 | 1.0001 | 1.0007 | 1.0010 |
| 5 | 1.0006 | 0.9999 | 1.0007 | 1.0011 |
| 6 | 1.0005 | 0.9999 | 1.0007 | 1.0011 |
| 7 | 1.0005 | 0.9999 | 1.0008 | 1.0012 |
| 8 | 1.0005 | 0.9998 | 1.0008 | 1.0012 |
| 9 | 1.0004 | 0.9996 | 1.0008 | 1.0012 |
| 10 | 1.0003 | 0.9994 | 1.0008 | 1.0012 |
| 11 | 1.0002 | 0.9992 | 1.0008 | 1.0012 |
| 12 | 1.0003 | 0.9992 | 1.0008 | 1.0012 |
| 13 | 1.0006 | 0.9992 | 1.0009 | 1.0012 |
| 14 | 1.0006 | 0.9991 | 1.0009 | 1.0012 |
| 15 | 1.0006 | 0.9989 | 1.0009 | 1.0012 |
| 16 | 1.0006 | 0.9988 | 1.0009 | 1.0012 |
| 17 | 1.0006 | 0.9987 | 1.0010 | 1.0012 |
| 18 | 1.0006 | 0.9987 | 1.0011 | 1.0014 |
| 19 | 1.0007 | 0.9986 | 1.0012 | 1.0015 |
| 20 | 1.0007 | 0.9985 | 1.0013 | 1.0015 |

Year zero is the benchmark year, to which the variables are indexed.
ALY is adjusted labor income; KY is private capital income; GRP is gross regional product; DYH is disposable household income.

Table 3. Effects on Migration of Private Capital and Labor (millions)

| Year | LMIG | KMIG |
|---|---|---|
| 0 | 0.000 | 0.000 |
| 1 | 18.408 | 9.564 |
| 2 | 0.120 | -1.186 |
| 3 | 0.000 | 2.328 |
| 4 | 0.000 | 0.002 |
| 5 | 1.297 | 0.023 |
| 6 | -0.001 | -0.786 |
| 7 | 1.958 | 0.150 |
| 8 | 0.004 | -0.792 |
| 9 | 0.000 | -1.466 |
| 10 | -0.344 | -1.446 |
| 11 | 0.000 | -1.878 |
| 12 | 0.001 | 0.350 |
| 13 | 0.001 | 0.288 |
| 14 | 0.003 | 0.117 |
| 15 | 0.000 | -0.413 |
| 16 | -0.374 | -0.119 |
| 17 | 1.586 | 0.689 |
| 18 | 2.030 | 0.897 |
| 19 | 2.027 | 0.888 |
| 20 | 0.829 | 0.320 |
| Total | 27.185 | 7.530 |

LMIG is labor migration; KMIG is private capital migration.

Table 4. Effects on Regional Prices

| | | | | PR | | | | PX | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | PT | PL | PK | Agr | Min | Man | Ser | Agr | Min | Man | Ser |
| 0 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1 | 1.000 | 1.001 | 1.00004 | 1.000 | 1.000 | 0.999 | 1.001 | 1.000 | 1.000 | 0.999 | 1.001 |
| 2 | 0.999 | 1.000 | 0.9999 | 1.000 | 1.000 | 0.999 | 1.003 | 1.000 | 1.000 | 1.000 | 1.003 |
| 3 | 1.000 | 1.000 | 1.00001 | 1.000 | 0.999 | 0.999 | 1.003 | 1.000 | 1.000 | 1.000 | 1.003 |
| 4 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 0.999 | 1.003 | 1.000 | 0.999 | 1.000 | 1.002 |
| 5 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 0.999 | 1.003 | 1.000 | 1.000 | 1.000 | 1.002 |
| 6 | 1.000 | 1.000 | 0.9999 | 1.000 | 0.999 | 0.999 | 1.002 | 1.000 | 1.000 | 1.000 | 1.002 |
| 7 | 1.000 | 1.000 | 1.0000 | 1.000 | 0.999 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.002 |
| 8 | 1.000 | 1.000 | 0.9999 | 1.000 | 0.999 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 9 | 1.000 | 1.000 | 0.9999 | 1.000 | 0.999 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.002 |
| 10 | 1.000 | 1.000 | 0.9999 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 11 | 1.000 | 1.000 | 0.9999 | 1.000 | 1.000 | 0.999 | 1.001 | 1.000 | 1.000 | 0.999 | 1.001 |
| 12 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.001 | 1.000 | 1.000 | 0.999 | 1.001 |
| 13 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.001 | 1.000 | 1.000 | 0.999 | 1.001 |
| 14 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 15 | 1.000 | 1.000 | 0.9999 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.002 |
| 16 | 1.000 | 1.000 | 0.9999 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 17 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 18 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 19 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 0.999 | 1.001 |
| 20 | 1.000 | 1.000 | 1.0000 | 1.000 | 1.000 | 0.999 | 1.002 | 1.000 | 1.000 | 1.000 | 1.001 |

PT is price of land, PL is labor wage, PR is regional price, PK is private capital price, and PX is price faced by producers. Import price and export price, which are exogenously controlled, remained at 1.00 throughout the simulation. In some years, the changes in prices were so small that they do not appear in the table due to rounding.

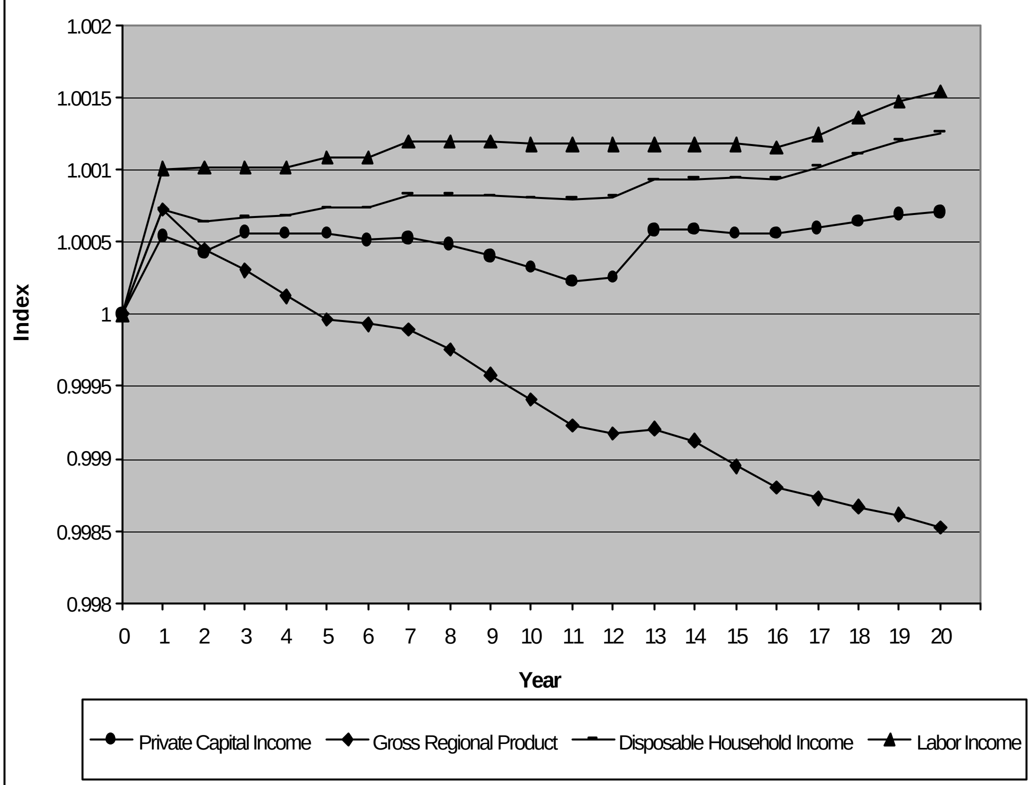


**Figure 1. Changes in Income and GRP Relative to Base Year**

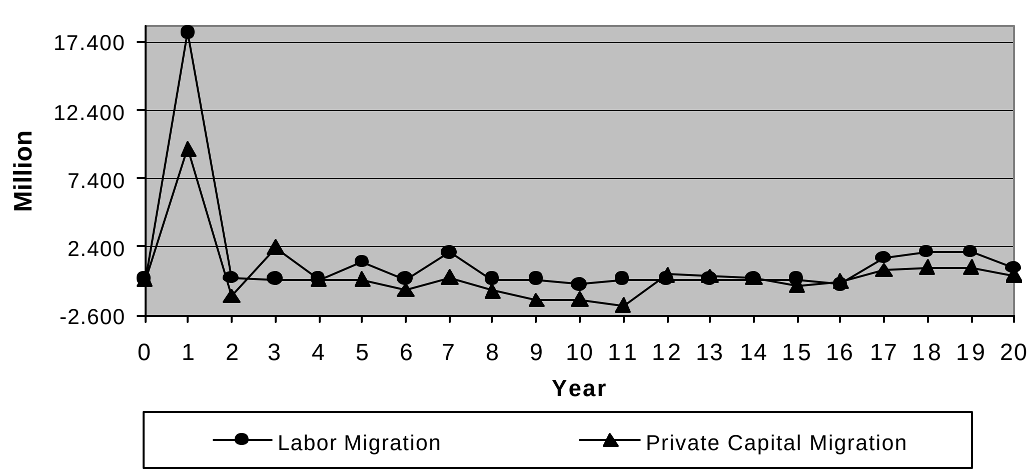


**Figure 2. Effects on Labor and Capital Migration**

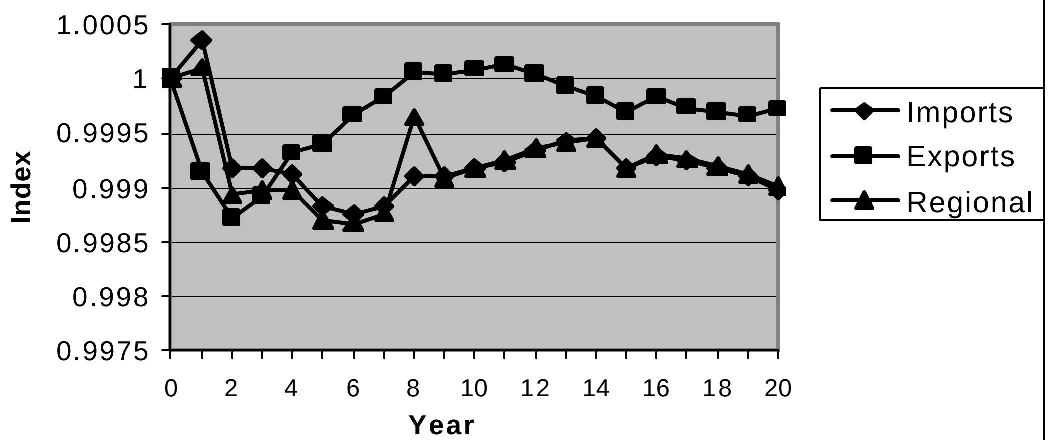


**Figure 3. Public Capital Effects on Agricultural Production**

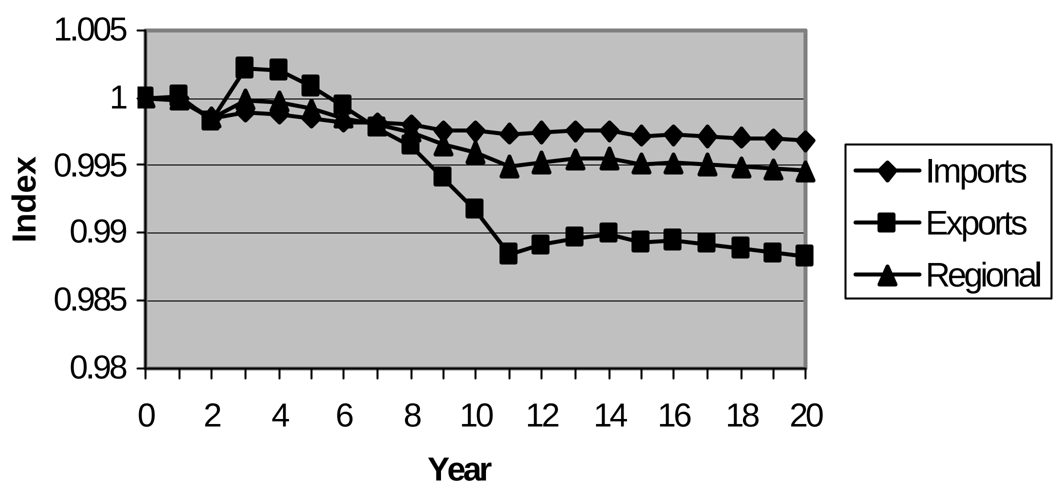


**Figure 4. Public Capital Effects on Mining Production**

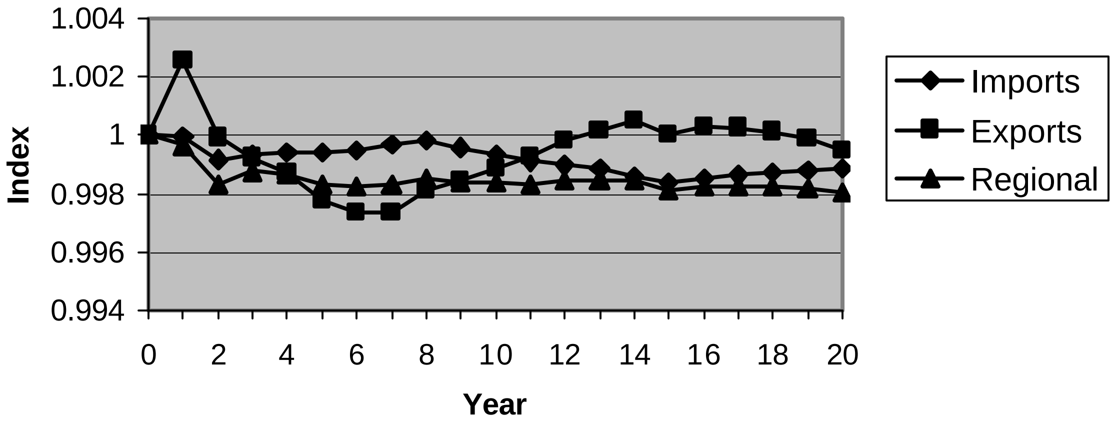


**Figure 5. Public Capital Effects on Manufacturing Production**

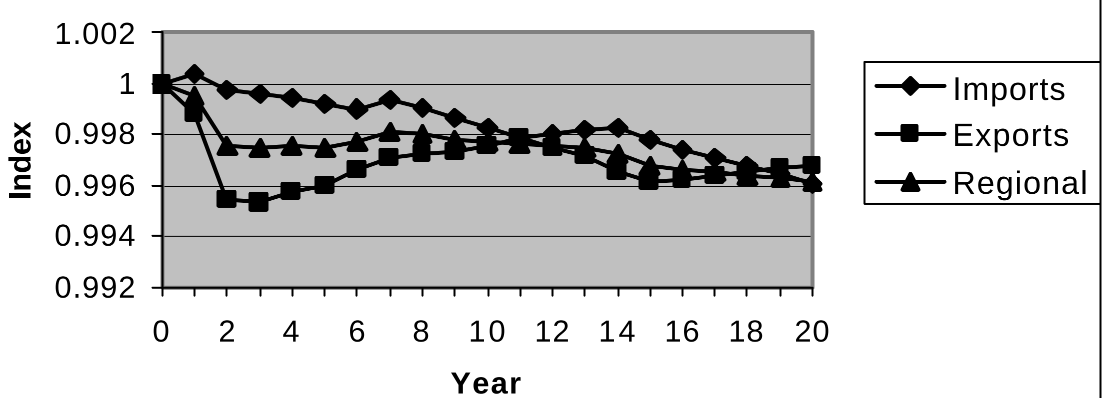


**Figure 6. Public Capital Effects on Services Production**

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**Using IMPLAN to Monitor Economic Change in Rural Areas of Egypt and Puerto Rico**[1]

Wilbur R. Maki[2]

# Modeling a Region's Economy

An abundance of research projects, statistical databases, and scholarly papers are available for building economic modeling systems to monitor and predict the impact of endogenous change on the demand for food products, not only positive changes attributed to the adoption of new technologies, but also negative changes attributed to restrictive institutional arrangements among farmers and property owners.[3] Egypt's agricultural regions are characterized by low productivity of farm and non-farm business enterprise, along with increasing numbers of unemployed workers and many discouraged workers who are not included in the unemployed labor force statistics, much as in Puerto Rico.

## MELLOR-RANADE MODEL

We present, first, a multi-equation market equilibrium model of Egypt's economy by Professors Mellow and Ranade to study the effects of various outside or exogenous variables, like total capital stock and labor force and technological change in agriculture, on endogenous variables, like labor in agriculture, capital in non-agricultural tradeables, prices of agricultural and non-agricultural tradeables and non-tradeables, and the proportion of total employment in each of the two tradeable sectors.[4] The three-sector model and its applications are instructive simplifications of Egypt's economy.[5]

Professors Mellor and Ranade argue, from the five model simulations, that increases in GDP depend largely on the growth of tradeable sectors while increases in employment depend largely on the growth of non-tradeable sectors.[6] While agriculture has similar proportions of GDP and employment; the urban tradable sector has nearly four times as high a share of GDP as of

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[3] Numerous studies of Egypt's economy exist of which several are cited in the Selected Bibliography. Two input-output models are available—one for fiscal year 1997, which includes an extensive social accounting matrix (SAM) based in part on survey data, the other for fiscal year 2001. Input-output models are available, also, that address the Puerto Rico economy and its changing industry composition.

[4] Two Cobb-Douglas production functions with land, labor, and capital as the input variables, plus technological change, are central elements of an eight equation model of Egypt's economy (Mellor and Ranade, 2002). Total labor and total capital are given values. Output of the non-tradeable sector is assumed proportional to total labor input. Market equilibrium values are derived for each of the three input variables-and the demand for non-tradeable by differentiating the three output-generating functions and, then, equating (1) the marginal products of labor and capital and (2) the supply of non-tradeables and the demand for it by labor.

[5] The base case of rapid balanced growth assumes a one percent increase in irrigated area; a five percent rate of technological change in agriculture; a two percent rate of technological change in urban tradeable sector; an eight percent rate of growth of the capital stock; and a labor force growth rate of 2.8 percent (Mellor and Ranade, page 15). The authors note the five percent rate of technological change in agriculture is consistent with a three percent rate of increase of crop and animal yields and a two percent increase in productivity "resulting from change in output composition towards higher value and productivity crops, such as horticulture." The authors claim the eight percent in the capital stock is consistent with a saving/investment rate of 15 to 20 percent--the low end of the range for "fast growth middle income countries."

[6] Tradeable and non-tradeable sectors are, respectively, export-producing and "services," that is, localized activities with local markets.

employment; while the non-tradable sector has the relationship almost reversed—more than twice as high a share of employment as of GDP. Mellor and Ranade attribute these differences to differences in capital stock per worker (Mellow and Ranade, 2002).

The GDP differs greatly among the three sectors in the Mellor-Ramade study, attributed, in part, to the different factor (land, labor, capital) shares for the three sectors (table 1). The recipients of income from labor and land spend heavily on non-tradeables, while the recipients of capital income, including human capital, spend heavily on tradeables. The dominant share of income in the urban sector is to capital. Mellor and Ranade found that "growth of the urban tradeable sector has only a modest impact on the employment-dominated non-tradeable sector. Agriculture, in contrast, has factor shares largely to farmers with income from land and labor. This income is spent largely in the rural non-tradeable sector."

**Table 1. Employment and GDP Shares and Factor Shares, Egypt, 1998 (percent)**

| | Employment | GDP | Share of Total GDP | | | |
|---|---|---|---|---|---|---|
| **Sector** | **Proportion** | **Proportion** | **Labor** | **Capital** | **Land** | **Total** |
| **Rural:** | | | | | | |
| **Agriculture (Tradeable)** | 23 | 17 | 55 | 10 | 35 | 100 |
| **Nontradeable** | 43 | 18 | 100 | 0 | 0 | 100 |
| **Subtotal** | 66 | 35 | | | | |
| **Urban:** | | | | | | |
| **Tradable** | 15 | 57 | 10 | 90 | 0 | 100 |
| **Nontradeable** | 19 | 8 | 100 | 0 | 0 | 100 |
| **Subtotal** | 34 | 65 | | | | |
| **Total** | 100 | 100 | | | | |
| **Summary:** | | | | | | |
| **Agriculture** | 23 | 17 | 55 | 10 | 35 | 100 |
| **Urban Tradeable** | 15 | 57 | 10 | 90 | 0 | 100 |
| **Non-tradeable, total** | 62 | 26 | 100 | 0 | 0 | 100 |
| **Total** | 100 | 100 | | | | |

Source: Mellor and Ranade, 2002

Distribution of value added among its recipients is only part of the story. Location of income recipients is important, also. For Puerto Rico, direct income of recipients residing outside Puerto Rico account for an increasingly larger share of total value added. This loss of income to Puerto Rico residents is represented as a declining share of Gross Domestic Product allotted to National Income in the National Income and Product Accounts.

## SAM Models for Egypt and Puerto Rico

A National SAM model for Egypt and a Commonwealth SAM model for Puerto Rico contain the essential data for representing the structure of the two economies. The models are disaggregated version of the National and Commonwealth economic accounts. They evolve from inter-industry transactions tables that include many variables and parameters with much greater detail than in the Mellor-Ranade models.

## National and Commonwealth models

The model findings, like industry production, are available to compare with industry employment for measures of industry productivity from one period to the next. They show industry output, value added, imports, and employment for each industry. They show also intermediate and final demands for the converted commodity supplies of the industry outputs. The intermediate demands refer to the industry purchases of commodity inputs. They form, together with the commodity imports and factor inputs, the input-output functions for each industry. The distribution of commodity supplies to the final demand sectors represents the commodity purchases by households, governments, and businesses, i.e., private capital formation, and, also, exports.

The Egypt IMPLAN-SAM regional models include a national model and two regional models—Lower Egypt and Upper Egypt. The Puerto Rico SAM models would include the San Juan metropolitan core area and one or more of dominantly rural regions to the south and west. Each regional model generates the six series of activity measures, plus the Rest of Nation (RON) exports and imports for the given region,

## Regional models

The IMPLAN-SAM software programs generate the Rest of Nation (RON) transactions and transfers and, consequently, the individual institutional sales and receipts entries. Only the RON totals are identified for the individual sectors in Figure 1. The excesses and deficits in each sector are balanced for each region with the excesses being exported to the RON sectors and deficits being imported from corresponding RON sectors. Foreign exports and imports are calculated for each region before initiating the sector balancing procedures. Each sector has several sub-sectors. The industry and commodity sectors, for example, have 35 sub-sectors in the Egypt regional models, while the factor and institution sectors each have four sub-sectors.

The regional models are characterized by their dependence on parameters and totals from their respective national and commonwealth models. They differ only because of differences in the employment estimates for each sector in each region and parameters calculated from their national or commonwealth models. They provide an initial set of regional outcome variables, like industry inputs, outputs, value added payments, and domestic (RON) imports and exports. Together, with estimates of industry employment, we generate initial measures of industry productivity, that is, output per worker, for productivity comparisons between sectors and regions, from one period to the next.

Figure 1. IMPLAN-SAM regional model framework

| | | Region | | | | | | | | Rest of Nation (RON) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| | **Region** | | | | | | | | | | | | | | | | | |
| 1 | Industry | | X | | | | | X | X | | | | | | | | | X |
| 2 | Commodity | X | | | X | | | X | X | | | | | | | | | X |
| 3 | Factors | X | | | | | | | | | | | | | | | | X |
| 4 | Institutions | | X | X | X | X | | X | X | | | | | | | | | X |
| 5 | Enterprises | | | | | | | | | | | | | | | | | X |
| 6 | Capital | | | | | | X | X | X | | | | | | | | | X |
| 7 | RON total | X | | X | X | | X | X | X | | | | | | | | | X |
| 8 | Foreign | X | | X | X | | X | X | X | | | | | | | | | X |
| | **Rest of Nation** | | | | | | | | | | | | | | | | | |
| 1 | Industry | | | | | | | | | | X | | | | | X | X | X |
| 2 | Commodity | | | | | | | | | X | | | X | | | X | X | X |
| 3 | Factors | | | | | | | | | X | | | | | | X | X | X |
| 4 | Institutions | | | | | | | | | | X | X | X | X | | X | X | X |
| 5 | Enterprises | | | | | | | | | | | | | | | | | X |
| 6 | Capital | | | | | | | | | | | | | | X | X | X | X |
| 7 | RON total | | | | | | | | | X | | X | X | | X | X | X | X |
| 8 | Foreign | | | | | | | | | X | | X | X | | X | X | X | X |
| 9 | Total | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | |

# Monitoring Industry Activity

The primary purpose of the Egypt and Puerto Rico IMPLAN-SAM modeling systems described earlier is to measure and, then, monitor key outcome indicators of regional economic growth and change. These outcome variables—employment, production, value added, and domestic imports and exports from a given region to the Rest of Nation- relate to the larger issues, like the divergence of Gross National Product from Gross Domestic Product and the increasing concentration of poverty in rural areas (El-Said, Lofgren, and Robinson, 2001).

## OUTPUT AND EMPLOYMENT

Output and employment measures are components of a commonly used measure of productivity, namely, output per worker. Estimates of output and employment include all sectors and are central to the measuring and monitoring of industry activity and its productivity—the "engine of growth" (Lewis, 2004). A breakdown of employment by occupation or skill level with corresponding estimates of output would provide a further refinement of current measures of productivity.

While the focus of this study for Egypt is on its food processing sector, productivity improvements in Egypt's agriculture and other related sectors are taken into account in the assessments of employment and income changes in each of Egypt's regional economies (Mellor and Gavian, 1999). Location of food processing sector clusters in or near major metropolitan areas with the most promising growth in jobs and income is consistent with efforts to improve overall industry productivity in these industry clusters (Porter, 1998). Location of food processing sector clusters in or near major metropolitan areas with the most promising growth in jobs and income is consistent with efforts to improve the sector's productivity and its competitive position in local and global markets.

Table 2. Ranking projected demand for labor and selected market indicators, Puerto Rico, 2001-2004

| Governorate | Food Proc. Emp (1995) | | Labor Force | | Unemployment | | Rate | Market Demand | |
|---|---|---|---|---|---|---|---|---|---|
| | (thou.) | (%) | (thou.) | (%) | (thou.) | (%) | (%) | (thou.) | (%) |
| Lower Egypt: | | | | | | | | | |
| Sharkiya | 23.2 | 7.7 | 1,332 | 7.1 | 127 | 8.5 | 9.5 | 72 | 5.1 |
| Ismailiya | 4.4 | 1.5 | 231 | 1.2 | 19 | 1.2 | 8.2 | 54 | 3.8 |
| Kalyobiya | 16 | 5.3 | 1,075 | 5.7 | 68 | 4.5 | 6.3 | 44 | 3.1 |
| Damietta | 4.9 | 1.6 | 293 | 1.6 | 21 | 1.4 | 7.2 | 28 | 2.0 |
| Dakahilya | 16 | 5.3 | 1,458 | 7.7 | 174 | 11.7 | 11.9 | 29 | 2.0 |
| Gharbeyia | 17.1 | 5.7 | 1,214 | 6.4 | 118 | 7.9 | 9.7 | 25 | 1.8 |
| Monofiya | 13.9 | 4.6 | 1,024 | 5.4 | 55 | 3.7 | 5.4 | 24 | 1.7 |
| Beheira | 11.8 | 3.9 | 1,270 | 6.7 | 167 | 11.2 | 13.1 | 21 | 1.5 |
| Kafr El Sheikh | 8.2 | 2.7 | 710 | 3.8 | 73 | 4.9 | 10.3 | 14 | 1.0 |
| Total | 115.5 | 38.3 | 8607 | 45.6 | 822 | 55 | 9.6 | 311 | 22.0 |
| Upper Egypt: | | | | | | | | | |
| Qena | 13.9 | 4.6 | 546 | 2.9 | 54 | 3.6 | 9.9 | 8 | 0.6 |
| Sohag | 8.9 | 3 | 824 | 4.4 | 81 | 5.5 | 9.8 | 7 | 0.5 |
| Aslut | 5.9 | 2 | 719 | 3.8 | 79 | 5.3 | 11.0 | 7 | 0.5 |
| Aswan | 6.8 | 2.3 | 262 | 1.4 | 50 | 3.3 | 19.1 | 5 | 0.4 |
| Luxor | 0.7 | 0.2 | 92 | 0.5 | 2 | 0.1 | 2.2 | 2 | 0.1 |
| Total | 36.2 | 12.1 | 2443 | 13 | 266 | 17.8 | 10.9 | 29 | 2.1 |
| Other areas: | | | | | | | | | |
| Urban | 89.5 | 29.8 | 3896 | 20.6 | 184 | 12.3 | 4.7 | 787 | 55.5 |
| Middle Egypt\ | 55.5 | 18.6 | 3673 | 19.4 | 187 | 12.5 | 5.1 | 273 | 19.3 |
| Frontier Egypt | 2.6 | 0.9 | 276 | 1.4 | 33 | 2.1 | 12.0 | 20 | 1.3 |
| Total | 147.6 | 49.3 | 7845 | 41.4 | 404 | 26.9 | 5.1 | 1080 | 76.1 |
| Total, all areas (27) | 300 | 100 | 18,895 | 100 | 1,492 | 100 | 7.9 | 1,420 | 100.0 |

Source: SEAM, 1996; Radwan, 2003

Egypt's regional statistics point to large regional employment and inter-regional trade imbalances (Table 2). They show, for example, high unemployment rates in both Upper Egypt and Lower Egypt**.** Middle Egypt has consistently lower rates of unemployment (Radwan, 2003). The urban regions, except Suez, also have consistently lower rates of unemployment. Projected demand for labor is highest in the two of the four urban regions—Cairo and Alexandria, and also the Giza Governorate in Middle Egypt. Conversely, the projected demand for workers is much larger for Lower Egypt than Upper Egypt—311,000 versus 29,000, or 23.0 percent and 2.5 percent, respectively, of the total. The two regions together account for 25.5 percent of the total projected demand for workers. The remaining 74.5 percent is projected largely in the four urban Governorates with 56.2 percent of the total.

Food-processing plants are closer to the final markets for food products than their farm supply sources of livestock, dairy, and horticultural products. These facilities also are quite distant from the largest concentrations of unemployed and underemployed rural labor force. Hence, growth in the food processing sector is several stages removed from the actual creation of job opportunities in the areas of the highest concentrations of rural poverty, as in Upper Egypt.

## EXPORTS AND ECONOMIC BASE

Egypt's commodity exports totaled to US$14,735 million while commodity imports totaled to US$20,867 million (Table 3). Producing sector imports, that is, imports exclusive of final demand sectors, totaled to US$12,942 million. The top seven foreign exports sectors in Egypt show positive net exports on both total and producing sector accounts. Total foreign exports for Puerto Rico exceed those for Egypt by more than nine billion dollars. Total foreign imports are less than total foreign exports. Unlike Egypt, Puerto Rico has a positive net export balance on both total and producing sector accounts.

Export and import measures, when tracked from one year to the next, show the changing contributions of a region to its trade balances and gross domestic product and income. National income and product accounts show a country's exports and imports for selected sectors and broad sector aggregations. They do not show the originating region of the commodity shipments within a country nor the commodity shipments from one region to another. The regional input-out model components generate tables of interregional commodity flows that have a secondary value in producing regional economic base models and the long-term economic base multipliers.

## VALUE ADDED AND INCOME

Total value added for Egypt in fiscal year 2001 was twice as large as for Puerto Rico (Table 4). Estimates of the employed labor force for each the 32 sectors are lacking for Egypt, but they are available for Puerto Rico for the 1992 fiscal year, as well as later years. [7] The most recent input-output data, however, are only for the 1992 fiscal year. These estimates show a higher proportion of employment in the high productivity sectors in Puerto Rico than in Egypt, as measured by value added per worker. Agricultural value added per worker in Puerto Rico is among the lowest of all sectors, exceeded only by textile products manufacturing. The processed food products sector is also in the low value added per worker group.

[7] Egypt's IMPLAN-SAM model described by Dr. Bahloul has 35 sectors.

**Table 3. Exports and imports of specified sectors, Egypt, 2000/2001.**

| | | Exports | Imports | | Net Exports | |
|---|---|---|---|---|---|---|
| **Industry** | **SIC Code** | **Total** | **Total** | **Sector** | **Total** | **Sector** |
| | | **(mil. $)** | **(mil.$)** | **(mil.$)** | **(mil.$)** | **(mil.$)** |
| Ginning | 0724 | 218 | 67 | 67 | 151 | 151 |
| Mining | 10-14 | 1,782 | 57 | 57 | 1,725 | 1,725 |
| Textiles | 22 | 568 | 312 | 273 | 256 | 295 |
| Petroleum products | 29 | 875 | 255 | 14 | 620 | 861 |
| Transportation | 40-47 | 3,903 | 912 | 761 | 2,991 | 3,142 |
| Trade , finance and insurance | 50-57, 60-64, 66-67 | 2,029 | 1,639 | 1,536 | 390 | 493 |
| Restaurants and hotels | 70 | 2,129 | 1,509 | 224 | 620 | 1,905 |
| Top 7 exporters | | 11,286 | 4,685 | 2,866 | 6,601 | 8,420 |
| Other agriculture | 01-02, 07-09, ex 0133, 0724 | 236 | 944 | 328 | -708 | -93 |
| Processed food | 201-5, 207, 209 | 529 | 3,074 | 2,226 | -2,545 | -1,696 |
| Clothes and leather shoes | 23 | 710 | 1,022 | 860 | -312 | -150 |
| Chemical industry | 28 | 570 | 1,304 | 1,029 | -734 | -458 |
| Non metal products | 32 | 143 | 674 | 618 | -531 | -474 |
| Basic metal products | 33 | 294 | 875 | 599 | -581 | -305 |
| Other industries | 38-39 | 120 | 556 | 103 | -437 | 17 |
| Private services | 71-89 | 276 | 504 | 351 | -228 | -75 |
| Next 8 largest exporters | | 2,879 | 8,954 | 6,113 | -6,075 | -3,235 |
| Sugar cane | '0133 | -- | -- | -- | -- | -- |
| Construction and maintenance | 15-17 | 0 | 1,483 | 1,483 | -1,483 | -1,483 |
| Sugar products | 206 | -- | -- | -- | -- | -- |
| Beverages | 208 | 23 | 93 | 86 | -70 | -63 |
| Cigarettes | 21 | 30 | 231 | 216 | -201 | -186 |
| Wood and furniture | 24-25 | 38 | 768 | 522 | -730 | -484 |
| Paper and paper products | 26 | 12 | 211 | 103 | -199 | -92 |
| Printing and publishing | 27 | 26 | 225 | 216 | -199 | -190 |
| Rubber and rubber products | 30 | 13 | 159 | 62 | -146 | -50 |
| Leather and leather products | 31 | 38 | 52 | 49 | -14 | -11 |
| Metal products | 34 | 49 | 494 | 270 | -445 | -221 |
| Non electrical machines | 35 | 12 | 985 | 60 | -974 | -49 |
| Electrical machines | 36 | 35 | 1,561 | 259 | -1,525 | -224 |
| Transport vehicle | 37 | 77 | 776 | 445 | -699 | -368 |
| Electricity | 48 | 0 | 122 | 122 | -122 | -122 |
| Housing, utilities, and real estate | 49, 65 | 0 | 2 | 2 | -2 | -2 |
| Bottom 16 exporters | | 352 | 7,162 | 3,897 | -6,810 | -3,544 |
| Total | | 14,735 | 20,867 | 12,942 | -6,132 | 1,792 |

**Source: Egypt Planning Board, 2003. Converted 4.15 LE to 1 USD.**

**Table 4 Value added and employment, by sector, Egypt (2001) and Puerto Rico (1992).**

| | | Egypt | Puerto Rico | | Egypt | Puerto Rico | |
|---|---|---|---|---|---|---|---|
| Sector | SIC Code | TVA | TVA | Employment | VA/Tot | VA/Tot | VA/Emp |
| | | (mil.US$) | (mil.US) | -1,000 | (%) | (%) | (1,000US$) |
| Agriculture | 01-09 | 11,854 | 425 | 25.3 | 16.2 | 1.1 | 16.8 |
| Mining | 10-14- | 3,980 | 34 | 1.1 | 5.4 | 0.1 | 30.5 |
| Construction and maintenance | 15-17 | 4,452 | 765 | 37.9 | 6 | 2 | 20.2 |
| Processed food | 201-5, 207, 209 | 1,460 | 414 | 17.6 | 2 | 1.1 | 23.5 |
| Sugar products | 206 | -- | 301 | 2.4 | -- | 0.8 | 127.4 |
| Beverages | 208 | 427 | 1,691 | 4.4 | 0.6 | 4.5 | 381.7 |
| Cigarettes | 21 | 782 | 189 | 3 | 1.1 | 0.5 | 63.9 |
| Textile products | 22 | 1,983 | 45 | 4.9 | 2.7 | 0.1 | 9.2 |
| Clothes and leather shoes | 23 | 2,741 | 536 | 12.6 | 3.7 | 1.4 | 42.6 |
| Wood and furniture | 24-25 | 564 | 61 | 2.2 | 0.8 | 0.2 | 27.4 |
| Paper and paper products | 26 | 260 | 74 | 1.5 | 0.4 | 0.2 | 48 |
| Printing and publishing | 27 | 400 | 176 | 4.9 | 0.5 | 0.5 | 35.6 |
| Chemical industry | 28 | 1,380 | 6,847 | 20.9 | 1.9 | 18.2 | 327.9 |
| Petroleum products | 29 | 692 | 302 | 6.8 | 0.9 | 0.8 | 44.7 |
| Rubber and rubber products | 30 | 83 | 196 | 2.2 | 0.1 | 0.5 | 87.2 |
| Leather and leather products | 31 | 179 | 129 | 4.5 | 0.2 | 0.3 | 28.5 |
| Non metal products | 32 | 2,062 | 187 | 5 | 2.8 | 0.5 | 37.5 |
| Basic metal products | 33 | 1,276 | 43 | 0.4 | 1.7 | 0.1 | 99.3 |
| Metal products | 34 | 445 | 114 | 2.9 | 0.6 | 0.3 | 39.1 |
| Non electrical machines | 35 | 100 | 503 | 1 | 0.1 | 1.3 | 528.9 |
| Electrical machines? | 36 | 506 | 1,289 | 16.9 | 0.7 | 3.4 | 76.1 |
| Transport vehicle | 37 | 799 | 45 | 1.1 | 1.1 | 0.1 | 42.2 |
| Other industries | 38-39 | 237 | 1,040 | 10 | 0.3 | 2.8 | 104.1 |
| Transportation | 40-47 | 6,612 | 889 | 28.2 | 8.9 | 2.4 | 31.5 |
| Electricity | 48 | 1,375 | 705 | 7.4 | 1.9 | 1.9 | 95.9 |
| Housing, utilities, and real estate | 49, 65 | 1,706 | 3,727 | 21 | 2.3 | 9.9 | 177.9 |
| Trade , finance and insurance | 50-57, 60-64, 66-67 | 16,265 | 7,504 | 211.7 | 21.9 | 19.9 | 35.5 |
| Restaurants and hotels | 70 | 1,353 | 350 | 11 | 1.8 | 0.9 | 31.8 |
| Private services | 71-89 | 5,681 | 4,833 | 143.2 | 7.7 | 12.8 | 33.8 |
| Gov't services | 90 | 4,554 | 4,289 | 231.8 | 6.1 | 11.4 | 18.5 |
| Total or average | | 74,208 | 37,703 | 843.9 | 100 | 100 | 44.7 |

**Source: Egypt 2000/2001 I-O model; MIG, 1992 Puerto Rico IMPLAN model.**

In summary, value-added-per-worker ratios remain a partial measure of the economic impact of a given sector to a region's income. Needed also is the distribution of the value added among income recipients—a contribution of the forthcoming IMPLAN-SAM modeling system for

Egypt. A large share of the value added among sectors with the higher productivity goes to non-residents as returns on their capital investments in these sectors—investments that contribute to the higher productivity of these sectors.

# Targeting Regional Concerns

We identify, next, a series of concerns facing the people of Egypt and Puerto Rico and their regions that are segments of the broader issues cited earlier. We start with the earlier reported finding that "increases in GDP depend largely on the growth of tradable sectors while increases in employment depend largely on the growth of non-tradable sectors." We include topical assessments as follows:Finding new and expanding markets, achieving higher productivity of resources use, growing the economic base, and reducing poverty. A regionalized modeling system is capable of monitoring the impacts of changes in industry exports and other critical measures of regional economic well being as regional economies grow and expand. Each of these assessments would be based on the use of IMPLAN-SAM models constructed for the various regions of Egypt and Puerto Rico. These models provide development policy agencies with tools for tracking key activities associated with a region's and a nation's growth and development.

## FINDING NEW AND EXPANDING MARKETS

Implicit in any policy measures to increase the production of processed food products are corresponding increases in new and expanding markets for the products of the food processing industry. Further development of the processed food products industry in Egypt depends on finding new and expanding product markets for their products, not only abroad but domestically as import substitutes inside, as well as outside, a producing region. These industries, in the latter case, would become part of a region's economic base.

Finding new markets is quite easy. They are both local and regional, and also foreign. Reaching these markets with competitively priced goods and services and holding on to them in the face of severe competition from other regions in Egypt and from abroad is the difficult part.

Exports, that is, shipments of goods and services out of a region, are essential for a region's viability and survival. Exports, of course, are a measure of a region's economic base

Past efforts finding new and expanding markets for Puerto Rico's industries were tied to the inducements of capital subsidies, tax concessions, and low-cost labor. While foreign imports find new and expanding markets in Puerto Rico, locally-produced products face declining market shares for their products. Thus, finding new and expanding markets, even within the Commonwealth, is quite difficult. It depends on having local entrepreneurs willing to take the many risks facing a new or newly expanding business, with access to venture capital for developing the facilities and services and who can compete successfully in these markets.

## ACHIEVING HIGHER PRODUCTIVITY OF RESOURCE USE

Industry output per worker is a rough measure of industry productivity. Output per worker changes may occur because of shifts in output composition towards products with higher output per worker ratios or towards products with higher output per unit of capital measures that are attributed to employment. Also, increasing the average size of firm associated with higher productivity per worker. Achieving higher productivity of resource use is an important goal for both Egypt and Puerto.

Changes in industry output and value added accompany changes in industry employment and industry output per worker and per unit of capital stock, that is, investment in facilities and services. Higher productivity per worker or per capital unit support higher output levels with a given number of workers or capital units. Higher productivity helps reduce the total "marketing bill" facing the final consumer as well as making the final product more competitive in local markets. Implicit in efforts to improve the productivity of resource use is accelerating job creation and upgrading occupational skills.

## Accelerating job creation

Accelerating job creation is still another way of utilizing unemployed and underemployed labor and capital resources and thus achieving higher productivity of resource use. Growth of food processing industries contributes to a growing demand for agricultural products. Corresponding increases in worker earnings contributes, in turn, to growing demand for consumer products. Accelerating job creation is a critical goal for both Egypt and Puerto Rico development efforts.

Keys to increasing the growth of food processing industries are output-increasing investments and accessible market demands for the processed food products. Improving labor and capital productivity is extremely important. Currently, many food processing establishments are small—essentially farm kitchen operations that cater to nearby local customers. One without the other understandably leads to failure. Similarly, growth of a region's economic base depends on expanding markets for its exports-producing industries

Access to accurate and available decision information is still another requirement for accelerating job creation. Egypt's Ministry of Planning, the Ministry of Agriculture and Reclamation, and other agencies—public and private—recognizes the need for additional resources to meet this growing challenge of more adequate decision information, coupled with education and training to effectively use this information.

## Upgrading occupational skills

Upgrading occupational skills is a way of achieving higher productivity of resource use. Important, also, is increasing the size of firm—the larger firms presumably being more productive, especially with skill specialization and economies of scale. This is no easy task for rural businesses, however, given opportunities for migrating the new skills to other businesses in urban areas at higher levels of compensation. Upgrading occupational skill *in situ* is, nonetheless, a critical goal for both Egypt and Puerto Rico development efforts.

Problems of cooperation and communication understandably are less troublesome among less specialized firms in the low-income agricultural regions than among specialized firms in the larger urban places, provided institutions in these regions have the resources and capability to sustain programs of localized learning. Localized learning activities (Lorenzen, 2001) are currently of limited scope in Egypt's agricultural regions. Low-income areas must still acquire management and product quality training programs and incentives to "level the playing field" so that resident farmers and resident business owners can more successfully compete in export markets.

### GROWING THE ECONOMIC BASE

Growing the economic base depends on finding new and expanding markets for the exports of regional basic industries in Egypt and Puerto Rico. New and expanding markets provide incentives for achieving higher productivity of resource use (Madrick, 2002). For Egypt, the series projections of plausible future demands for Egypt's processed food products trigger corresponding changes in the production of industry production that would satisfy the project final demands.

Focus of the Puerto Rico SAM model is on the economic base of Puerto Rico and its industries and their contributions past and future growth (Weisskoff, 1985; Ruiz and Melendez, 1994). For Puerto Rico, the economic base of its regions has changed gradually from one dependent on exports of processed agricultural products, largely sugar cane, to manufacturing subsidized by low-taxes and low-cost labor and most recently to tourism and local import-replacing and export-producing industries.[8] Moreover, the earlier manufacturing industries were in large part owned by companies with headquarters outside Puerto Rico, thus contributing to the loss of income from locally-generated value added.

### REDUCING POVERTY

Reducing poverty is critical goal for both the Egypt and Puerto Rico development efforts that must take into account the two topical areas listed cited earlier-- achieving higher productivity of resource use and growing the economic base (Fergany, 1998).

## Policy Assessments

We illustrate, finally, use of the key economic indicators derived by the IMPLAN-SAM modeling systems in policy assessments of various measures to address the regional economic concerns cited earlier. In turn, discussion of policy alternatives provides useful feedback in constructing and using the IMPLAN-SAM modeling systems.

### PREDICTING REGIONAL IMPACTS

As noted earlier, the practical value of the IMPLAN-SAM modeling systems is in estimating the effects of changes in a region's income-generating activities and its consequences for regional residents. Use of the IMPLAN-SAM modeling systems in <u>benchmarking changes in the underlying conditions affecting rural employment, incomes, trade and poverty</u> is an important contribution of these systems. The individual industry multipliers, when applied to given changes in final demand, yield the predicted outcomes of changes in industry outputs, along with predicted changes in resource requirements.

Use of the IMPLAN-SAM begins with estimates of future demands for the various industry outputs:

[8] See, Weisskoff, 1985, for a well-documented, although critical, analysis of the earlier factory-based economy of Puerto Rico.

Local and regional markets dominate trade in industry outputs. For some industries, however, foreign exports are more profitable than local sales or exports to rest of nation, while for other industries foreign imports are essential for lack of locally-available inputs.

Domestic exports and imports are derived by the IMPLAN-SAM software package for each region. At the national level, domestic exports and imports are balanced to equal zero.

Once the basic IMPLAN-SAM modeling system is installed, one additional refinement of the database and modeling capabilities is the further breakdown of total employment into skilled and unskilled workers. Egyptian economy based on input accounting tables and their accompanying social accounting matrix for fiscal year 1997 (El Said, Lofgren, and Robinson, 2001). Elaborate on next step in enhancing value of employment change predictions.

Earned incomes of labor and capital resources are derived from the value added attributed to each sector in each region's economy.

Personal income relates directly to the consumption expenditures of households and government and capital spending of private businesses. These increases in consumption expenditures are not necessarily destined to purchases of domestically-produced goods and services. They may go largely to imports that are more readily available and competitively priced than the domestically-produced products. Personal income, along with income of businesses and governments, relates to the total value added that remains in a region or country. Poverty is increasingly a rural phenomenon in both Egypt and Puerto Rico. It can be identified from income levels of individual regions and areas within these regions.

## IDENTIFYING RESOURCE GAPS

Identifying resource gaps is an extra-curricular activity aided by access to the predicted regional impacts of changes in proposed policies affecting the demand for Egypt's and Puerto Rico's industry outputs that relate to improving the productivity of resource use and growing the economic base.

Findings from the regional IMPLAN-SAM models will help identify critical resource gaps

Education and training gaps become apparent from the findings on labor requirements of predicted changes in industry outputs associated with given policy external economic changes affecting final demands. Education and training gaps may be less important, however, than on-the-job training to improve the productivity of resource use (Lewis, 2004)

Public infrastructure gaps become apparent from the lack of public facilities and services for serving local industries trying to meet the projected increases in domestic and foreign export demands.

Private investment gaps become apparent from the lack of facilities and workers for producing the projected increases in domestic and foreign export demands. Private investments are lacking, also, for increasing the size of business to improve their competitive position for tapping new and expanding markets.

New business formation gaps become apparent from the unmet changes in final demands associated with projected changes in market demands and public policies. The deficit supplies of locally-produced goods and services may be traced to their small size and inability to compete successfully with imports. Local entrepreneurship is an increasingly important part of a region's viability and capacity for sustained economic growth.

Measures for improving the competitive position of rural and urban industries are targeted by the IMPLAN-SAM modeling efforts for Egypt and Puerto Rico. Expanding product markets encourage local entrepreneurs to invest in new products and new exports-producing businesses (Madrick, 2002). Efforts to improve the productivity of these businesses go hand-in-hand with improving their competitive position in local, regional, and global markets (Lewis, 2004). Lessening the export of factor income, that is, value added by a region's industry, would occur as these resources become available for producing the goods and services that compete successfully in local, regional, and global markets.

# Summary

In summary, we refer to two sets of tools for monitoring the outcomes we address. The first set of tools originates from the work of two groups of scholars focusing on Egypt's economy—(1) a social accounting model (SAM) prepared by associates of the International Food and Policy Research Institute and (2) a dynamic multi-sector model prepared by Professors Mellor and Ranade that simulates income consequences of various policy options. A second set of tools are the regional input-output modeling systems discussed elsewhere in this Conference that build on findings of both the social accounting and the dynamic multi-sector models. For this paper, the primary purpose of this second set of tools is to monitor changes in a region's—not only a nation's--key outcomes.

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# Economic Impact of Seven of the Eleven Member Organizations of Marketing Association of Rehabilitation Centers

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## Introduction

Marketing Association of Rehabilitation Centers (MARC) is a nonprofit 501 (c) (3) organization composed of eleven community rehabilitation centers located in western North Carolina. MARC members operate mission-based not-for-profit businesses that provide vocational training, pre-vocational services, residential services, employment, and community employment placement for individuals with disabilities. Individuals in the training programs earn money while learning about different jobs and developing work habits and skills necessary to succeed in today's workplace.

Rehabilitation centers contribute to the local economy by making purchases of goods and services and capital improvements available locally. Most rehabilitation center employees live in the local community and contribute to the local economy by spending the majority of their disposable income locally. Rehabilitation centers are actively engaged with group home operations and ancillary medical service providers such as occupational and physical therapists, and all contribute to the local economy.

Rehabilitation centers are often overlooked when local governmental officials or business and community leaders attempt to define or describe their local economy. In most instances, however, they have become one of the five or ten largest manufacturing industries within their local area. In an effort to call attention to the impact that each MARC member organization has on their individual local economy and community, an economic impact study of each organization was begun in the fall of 2003. As of November 2004, seven of the eleven MARC organizations have had their economic impact study completed, see Table 1. Marketing Association of Rehabilitation Centers. An economic impact study of each of the remaining MARC rehabilitation centers will be completed during the next eight months.

**TABLE 1. MARKETING ASSOCIATION OF REHABILITATION CENTERS**

| Rehabilitation Center | Service Area Counties | Economic Impact Study Completed |
|---|---|---|
| Haywood Vocational Opportunities | Haywood | Yes |
| Transylvania Vocational Services | Transylvania | Yes |
| Industrial Opportunities, Inc. | Cherokee, Clay, and Graham | Yes |
| Something Special Enterprises and Career Opportunities, Inc. | Henderson | Yes |
| Watauga Opportunities, Inc. | Watauga, Ashe, Avery, Mitchell, and Yancey | Yes |
| Webster Enterprises of Jackson County | Jackson, Macon, and Swain | Yes |
| Polk Vocational Services | Polk | Yes |
| Goodwill Industries | Buncombe and Madison | No |
| Foothills Industries of McDowell | McDowell | No |
| Vocational Opportunities of Cherokee, Inc | Qualla Boundary, Jackson and Swain | No |
| Rutherford Life Services | Rutherford | No |

## Census Information

According to the 2000 Census there were 55,606 persons between the ages of 16 and 64 with some form of a disability living in one of the counties of the seven MARC organizations that have had their economic impact study completed. In 2000, the total number of persons with a disability and employed was 29,689 or 53.4% of working aged persons with a disability; see Table 2, Working Aged Persons with a Disability and Employed, 2000.

**Table 2. Working Aged Persons with a Disability and Employed, *2000* ***

| Rehabilitation Center | Persons with a Disability | Number of Employed Persons with a Disability | Percent of Employed Persons with a Disability |
|---|---|---|---|
| Haywood Vocational Opportunities | 7,142 | 3,753 | 52.5% |
| Transylvania Vocational Services | 3,415 | 1,753 | 51.3% |
| Industrial Opportunities, Inc. | 6,054 | 2,808 | 46.4% |
| Something Special Enterprises and Career Opportunities, Inc. | 10,880 | 6,344 | 58.3% |
| Watauga Opportunities, Inc. | 15,400 | 8,035 | 52.2% |
| Webster Enterprises of Jackson | 10,369 | 5,689 | 54.9% |
| Polk Vocational Services | 1,307 | 2,346 | 55.7% |
| Total for Seven Rehabilitation Centers | 55,606 | 29,689 | 53.4% |

* Numbers and percentages are for county(s) within the service area of the rehabilitation center that has been listed.

The Census 2000 figure of 29,689 represents more than individuals earning a living and contributing to their local economy by purchasing consumer goods and services and owning or renting property. This figure represents individuals who are reducing or even ending public assistance all together putting an end to their own cycle of dependence on public support. Parents and other care givers no longer required to stay home can return to the local labor force and become contributors to their local economy.

By comparison, according to the 1990 Census, 7,036 or 29.9% of working aged persons with a disability were employed within the same area; see Table 3, Working Aged Persons with a Disability and Employed, 1990. Many persons with a disability who now work and live within one of the seven MARC service areas had their first work experience, job placement, and job training completed at their local rehabilitation center.

**Table 3. Working Aged Persons with a Disability and Employed, *1990* ***

| Rehabilitation Center | Persons with a Disability | Number of Employed Persons with a Disability | Percent of Employed Persons with a Disability |
|---|---|---|---|
| Haywood Vocational Opportunities | 3,228 | 934 | 28.9% |
| Transylvania Vocational Services | 1,442 | 480 | 33.3% |
| Industrial Opportunities, Inc. | 2,731 | 681 | 24.9% |
| Something Special Enterprises and Career Opportunities, Inc. | 4,167 | 1,376 | 33.0% |
| Watauga Opportunities, Inc. | 7,032 | 2,001 | 28.5% |
| Webster Enterprises of Jackson | 4,097 | 1,267 | 30.9% |
| Polk Vocational Services | 829 | 297 | 35.3% |
| Total for Seven Rehabilitation Centers | 23,526 | 7,036 | 29.9% |

* Numbers and percentages are for county(s) within the service area of the rehabilitation center that has been listed.

If not for the work of the seven rehabilitation centers providing job placement and job training the total of 29,689 in Table 2, in column "Number of Employed Persons with a Disability" would have been significantly smaller. If, for example, the 2000 Census percentage had remained the same as found in the 1990 Census, i.e., 29.9%, an additional 13,000 more people with a disability would not be working. In order to survive they probably would be collecting some form of public assistance.

## Methodology

The reason for doing an economic impact study for each MARC organization is to estimate the economic impact each has on their local area economy. The economic impact studies examine expenditures made in relationship to operations during a fiscal year. More specifically operational and capital improvement expenditures and wage spending by rehabilitation center employees. Estimates made on spending patterns are then used to arrive at a total economic impact on the individual rehabilitation center's service area in terms of total dollar amounts and jobs created.

To estimate the total economic impact a rehabilitation center has on the local economy, IMPLAN software modeling system and database is used. IMPLAN is an economic development tool that applies multipliers and performs an input-output analysis to estimate the economic impact of spending in the local community. Once dollar figures for goods and services purchased during the initial phase of spending have been estimated, dollar figures are entered into an IMPLAN generated model of the individual rehabilitation center's service area.

Direct dollars spent for goods and services identified by IMPLAN as items that are available in the local economy are traced by an input-output analysis as secondary impact dollar spending. Secondary impact dollars accumulate as a result of both indirect and induced effects. Indirect effects are secondary impacts that result from businesses that make expenditures in order to replenish goods and improve services that have been purchased by direct impact (initial) expenditures. Induced effects are secondary impacts resulting from an increase in household spending by employees who are hired, or current employees paid to work longer hours, to provide goods and services being purchased.

Estimates of secondary impacts are based on the multiplier effect, an economics principle that provides figures necessary to calculate total amount of spending that takes place as a result of the "ripple effect." The concept is that every dollar received by business owners and employees is re-spent, multiplying the initial sales by some factor and generating revenues in other sectors of the local economy. It should be noted that a portion of direct and secondary dollar spending goes for goods and services that are not produced in the local community as well as to pay taxes. Money used to purchase items that are not available in the local community and money used to pay state and federal taxes are dollars that leave the local economy, and so do not continue to circulate within the local community.

An economic impact analysis has been completed for seven of the eleven MARC rehabilitation centers. The total dollar amounts for each was added together to arrive at a total economic impact for the seven rehabilitation centers. Dollar amounts for retail sales were added together to determine the dollar amount spent and tax revenues collected. The number of rehabilitation center jobs were counted and number of jobs created due to spending were added together to provide a figure of total jobs.

## Results

The following tables show the initial phase of expenditures made by seven rehabilitation center operations, and economic impacts that result from those expenditures. Table 4, Initial Expenditures are first phase dollar spending that occurs within the local economy and includes rehabilitation center Operations - $1,480,559 and Employee Spending - $12,139,968. Employee spending is based on salary figures for the rehabilitation center employees less payroll taxes and benefits. The total initial expenditures amounts to $13,620,527 dollars spent in the local economy of the seven rehabilitation centers.

**Table 4. Initial Expenditures within the Local Economy**

| Rehabilitation Center | Operational Expenditures | Employee Spending | Total |
|---|---|---|---|
| Haywood Vocational Opportunities | $356,688 | $5,247,661 | $5,604,349 |
| Transylvania Vocational Services | $270,426 | $2,615,737 | $2,886,163 |
| Industrial Opportunities, Inc. | $94,935 | $2,280,600 | $2,375,535 |
| Something Special Enterprises and Career Opportunities, Inc. | $261,911 | $711,450 | $973,361 |
| Watauga Opportunities, Inc. | $407,000 | $624,595 | $1,031,595 |
| Webster Enterprises of Jackson | $25,130 | $329,675 | $354,805 |
| Polk Vocational Services | $64,469 | $330,250 | $394,719 |
| Total for Seven Rehabilitation Centers | $1,480,559 | $12,139,968 | $13,620,527 |

The initial expenditures subsequently initiate a series of spending and re-spending for goods and services in the local community that result in secondary impacts within the local economy. During each cycle of spending a portion of every dollar spent leaves the local economy while the remainder stays and continues to circulate. IMPLAN applied multipliers to produce dollar figures for the impacts that results from money being spent and circulated through the local economy. Table 5, Secondary Dollar Impacts are figures that were generated by IMPLAN software and includes rehabilitation center Operations - $739,889 and Employee Spending - $1,807,306. When added together the total secondary dollar impacts amounts to $2,547,195; these are dollars spent in the local economy.

**Table 5. Secondary Dollar Impacts within the Local Economy**

| Rehabilitation Center | Operational Expenditures | Employee Spending | Total |
|---|---|---|---|
| Haywood Vocational Opportunities | $209,460 | $799,094 | $1,008,554 |
| Transylvania Vocational Services | $153,203 | $340,307 | $493,510 |
| Industrial Opportunities, Inc. | $60,913 | $320,823 | $381,736 |
| Something Special Enterprises and Career Opportunities, Inc. | $104,442 | $128,545 | $232,987 |
| Watauga Opportunities, Inc. | $184,134 | $137,723 | $321,857 |
| Webster Enterprises of Jackson | $10,181 | $56,352 | $66,533 |
| Polk Vocational Services | $17,556 | $24,462 | $42,018 |
| Total for Seven Rehabilitation Centers | $739,889 | $1,807,306 | $2,547,195 |

Table 6, Total Dollar Impact is found by adding amounts from Table 4 and 5 to arrive at economic impacts that are directly related to rehabilitation center operations. When operational initial and secondary expenditures are added together the total amounts to a $2,220,448 economic impact. Employee spending amounts to a $13,947,274 economic impact. When added together the total dollar economic impact of the seven rehabilitation centers amounts to $16,167,722.

**Table 6. Total Dollar Impact within the Local Economy**

| Rehabilitation Center | Operational Expenditures | Employee Spending | Total |
|---|---|---|---|
| Haywood Vocational Opportunities | $566,148 | $6,046,755 | $6,612,903 |
| Transylvania Vocational Services | $423,629 | $2,956,044 | $3,379,673 |
| Industrial Opportunities, Inc. | $155,848 | $2,601,423 | $2,757,271 |
| Something Special Enterprises and Career Opportunities, Inc. | $366,353 | $839,995 | $1,206,348 |
| Watauga Opportunities, Inc. | $591,134 | $762,318 | $1,353,452 |
| Webster Enterprises of Jackson | $35,311 | $386,027 | $421,338 |
| Polk Vocational Services | $82,025 | $354,712 | $436,737 |
| Total for Seven Rehabilitation Centers | $2,220,448 | $13,947,274 | $16,167,722 |

One segment of the local economy, taxable retail sales, demands special attention because of the local sales tax revenues that it generates. The Federal Consumer Expenditure Report indicates that people in income brackets similar to rehabilitation center employees spend 48% of their disposable income on taxable retail items. Table 7. Retail Sales and County Tax Revenues makes use of IMPLAN generated data for employee spending of $13,947,274 to estimate a dollar amount of $6,715,667 in local retail sales. Retail sales of $6,715,667 when multiplied by 2.5%, the county portion of retail sales tax produces a tax revenue figure of $167,897.

**Table 7. Retail Sales and County Sales Tax Revenues**

| Rehabilitation Center | Employee Spending | Employee Retail Dollars Spent Locally | 2.5% Retail Sales Tax Revenues |
|---|---|---|---|
| Haywood Vocational Opportunities | $6,046,755 | $2,923,617 | $73,090 |
| Transylvania Vocational Services | $2,956,044 | $1,418,901 | $35,473 |
| Industrial Opportunities, Inc. | $2,601,423 | $1,248,683 | $31,217 |
| Something Special Enterprises and Career Opportunities, Inc. | $839,995 | $403,198 | $10,080 |
| Watauga Opportunities, Inc. | $762,318 | $365,913 | $9,148 |
| Webster Enterprises of Jackson | $386,027 | $185,293 | $4,632 |
| Polk Vocational Services | $354,712 | $170,262 | $4,257 |
| Total for Seven Rehabilitation Centers | $13,947,274 | $6,715,667 | $167,897 |

Employment is another way to examine how rehabilitation centers affect the local economy since expenditures made by their operations result in creation of jobs in their local community. Table 8, Job Creation Due to Spending are job figures that were generated by IMPLAN software. IMPLAN applied multipliers to produce job figures for impacts that resulted from money being spent and circulated through the local economy. The total economic impact of operations in terms of jobs created is 127. The seven rehabilitation centers employ 872 people, so the total number of jobs that are related to their operations is 999 jobs in their local community.

**Table 8. Job Creation Due to Spending**

| Rehabilitation Center | Rehabilitation Center Employment | Jobs Created | Total |
|---|---|---|---|
| Haywood Vocational Opportunities | 307 | 55 | 362 |
| Transylvania Vocational Services | 137 | 25 | 162 |
| Industrial Opportunities, Inc. | 212 | 22 | 234 |
| Something Special Enterprises and Career Opportunities, Inc. | 80 | 8 | 88 |
| Watauga Opportunities, Inc. | 67 | 10 | 77 |
| Webster Enterprises of Jackson | 29 | 4 | 33 |
| Polk Vocational Services | 40 | 3 | 43 |
| Total for Seven Rehabilitation Centers | 872 | 127 | 999 |

It should be noted that a large percentage of personal income is spent on housing, and regardless whether a resident of a housing unit is a homeowner or renter, property taxes must be paid. Assuming each of the 999 jobs related to rehabilitation center operational spending represents a person living in a separate housing unit, each individual will be contributing to their community's property tax revenues. So, although it would be difficult to estimate a total dollar amount, it can be stated that a percentage of wages that each of the 999 employees receives goes to pay property taxes.

## Summary

In an effort to call attention to the impact each MARC member organization has on their individual local economy and community, an economic impact study of each was begun in the fall of 2003. As of November 2004, an individual economic impact analysis for seven of the eleven MARC rehabilitation centers has been completed. The analysis has found that each rehabilitation center has had a significant economic impact upon their local economy in terms of dollars being spent, local tax revenues, and jobs.

A better understanding of the economic impact rehabilitation centers have had can be found by added together results of each of the seven completed studies. Census data for the seven rehabilitation centers indicates that 13,000 more individuals with disabilities were working in the year 2000 then you would expect based on 1990 Census data. Although it would be difficult to calculate, an additional benefit of individuals with severe disabilities who are now working is that their caregivers no longer must stay at home and can now enter the work force.

When added together initial expenditures and employee spending of the seven centers amounts to $13,620,527. These dollars circulate in and around the local economy and in so doing contribute significantly to the economic progress of the local area. A significant portion of the dollars that are spent during the initial expenditure phase leave the local economy, but the remaining dollars continue to circulate producing local economic impacts in terms of additional spending cycles and job creation. When the spending cycles have finished the total economic impact in terms of dollars spent in the local economy for goods and services is $16,167,722.

In terms of jobs, spending associated with the seven rehabilitation centers is responsible for creation of 127 jobs. At the seven rehabilitation centers there were 872 employees, and when 127 jobs are added the result is a total of 999 jobs. Retail sales associated with employee spending amounts to a total of $6,715,667 which produces retail sales tax revenues of $167,897. These amounts are not simply a one-year contribution to the local economy, but similar amounts are added yearly.

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# Construction of a U.S. Multiregional Input-Output Model Using IMPLAN

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## I. Introduction

Economists have become seriously interested in evaluating the socioeconomic impacts on the U.S. economy of terrorist attacks, since the Sep.11, 2001 attacks. Even an attack that does not involve many fatalities could cause enormous economic disruption. Also, the recent hurricanes to hit the southeastern U.S. raise similar questions. Alternative defensive and mitigation measures can best be evaluated by policymakers with better information on the nature of distributed impacts throughout the national economy. Such impacts can be estimated by tracing effects through inter-connected industries as well as inter-regional commodity flows.

To examine the full-costs through the U.S. economy using an integrated model of losses, spatial connections between states must be considered. A major problem, however, in developing integrated interregional-intrametropolitan models is how to combine not easily compatible databases. Although Chenery (1953) and Moses (1955) formulated an interregional framework based on the early discussion of Isard (1951), data problems still stymie applications This explains why a Chenery-Moses model has not been developed in recent years, in fact not since Polenske (1980) and Jack Faucett Associates (1983). Also, U.S. Commodity Transportation Survey data on inter-regional trade flows since 1977 has been discontinued. This data deficit can be met to some extent with the Commodity Flow Survey (CFS) from Bureau of Transportation Statistics (BTS), but current CFS data are incomplete with respect to interstate flows.

The primary purpose of this study is, therefore, to suggest a useful way to create trade flows between U.S. states so as to create a new National Interstate Economic Model (NIEMO) for the U.S. Direct economic impacts are often easily estimated in the aftermath of an attack. If plausible scenarios for the time-profile of reduced shipping facilities are available, spatially detailed indirect and induced economic effects can be estimated with a NIEMO-type model. Standard applications of IO determine indirect and induced impacts typically do not include interactions among industries and states. To estimate such short-term impacts, multi-regional models consisting of two sets of tables, regional coefficient tables and trade coefficient tables, are appropriate (Miller and Blair, 1985). These NIEMO-type Chenery-Moses models can be used to estimate inter-state industry effects as well as inter-industry impacts on each state. To proceed this way, it is necessary to calculate multi-regional industry coefficients among U.S. states; the regional tables that give us intra-regional industry coefficients by state and the interregional trade tables to give us trade coefficients by industry. This paper, therefore, will suggest a sequence of computational steps for estimating inter-state trade flows required to implement such a model.

To construct the trade tables - between all 50 states plus D.C. and the rest of the world -, we applied an Adjusted Flow Model, a Double constrained Fratar Model based on 1997 CFS and 2001 IMPLAN data. Due to the different industrial code systems that characterize the two data sources, however, reconciliation of the IMPLAN and CFS databases presented several problems which will be discussed as the next section, where what we have labeled the "USC (reconciled) Sectors" are developed to enable a match of two code systems used in the North American Industry Classification System (NAICS), the Bureau of Economic Analysis (BEA), or new 509 IMPLAN codes. In the third section of this paper, two methodologies, the Adjusted Flow Model and the Double constrained Fratar Model, are explained. As the results of methods developed in the third section, will show the estimated results in the fourth section.

## II. Data Reconciliation

The major problem in developing an interregional interindustrial model stems from the fact that it is difficult to obtain data representing U.S. trade flows between the states (Lahr, 1993). Since 1993, however, CFS data have been widely used, but there are problems. For example, the existence of many unreported values has required relying on other data sources for completeness. Since Polensky (1980) and Faucett Associates (1983), there has been no comprehensive inventory of flows for, probably these reasons.

The basic data of our study are from1997 CFS and 2001 IMPLAN. The 1997 CFS reports trade flows between U.S. states, although the flow data are not complete because of high sampling variability or disclosure of individual company status. Yet, it can be useful base-line to update to 2001 year using 2001 IMPLAN data. However, discordance between different code systems from different data sources is especially difficult when data reconciliation is attempted without any standardized and tested conversion bridge. To estimate 2001 trade flows from 1997 CFS, therefore, required a conversion table between the SCTG code system of 1997 CFS and IMPLAN code system, though this could not be one-to-one, between BEA and NAICS codes. <Figure-1> shows the data reconciliation process to create a SCTG-IMPLAN conversion bridge enabling aggregation 509 IMPLAN sectors to 43 SCTG sectors.

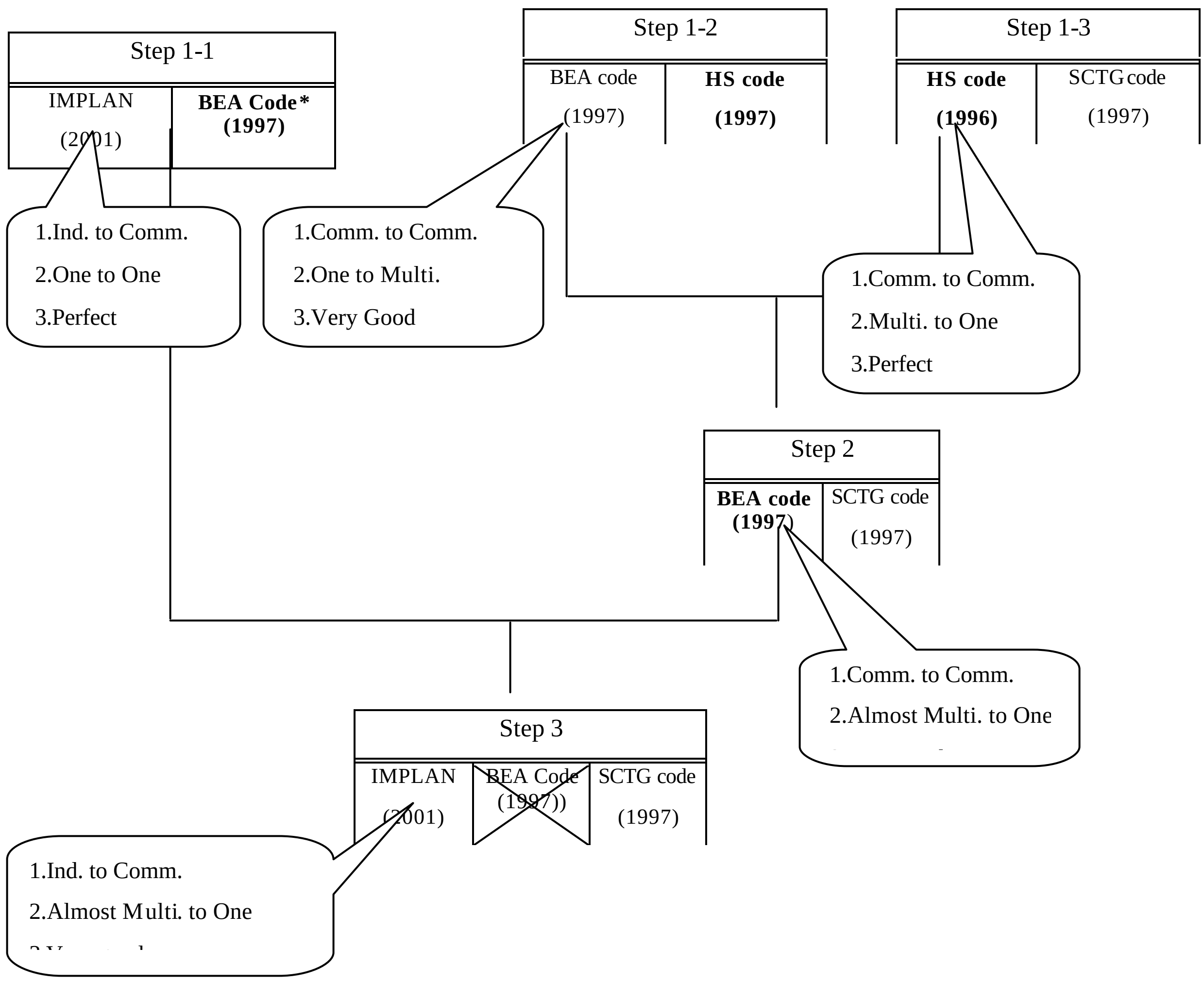
Another reconciliation work between IMPLAN and CFS data is concerned with the concept. In other words, the concepts in these two data sources should refer the same thing. For example, based on CFS definition, foreign imports which are transported from port of entry to the destination state, have been included in CFS inter-state commodity flow. However, in IMPLAN data, foreign imports refer the imports which are consumed in the local area. The foreign imports which are not consumed in the local area and transported to other state(s) are excluded from the state or county-level IMPLAN data. In order to make the concept of "inter-state commodity flow" consistent within these two data sources, Foreign Import in IMPLAN data are adjusted by dividing a ratio of 0.536, meaning proportion of sum of Foreign Imports of every States over total U.S. Foreign Import. Adjusted foreign imports will then include the foreign imports consumed in certain local area, as well as the foreign imports consumed in other states which use this certain local area as a port of entry. In this way, CFS and IMPLAN data could be reconciled from the concept point of view. We denote Remained IMPLAN Foreign Import as *RIFI*

(=0.536*Adjusted Foreign Imports), and denote IMPLAN Foreign Import as *OIFI* (=0.464*Adjusted Foreign Imports))

With the reconciliation, some minor manual adjustments were still required on the basis of judgment, using sector names of 5-digit SCTG and 6-digit NAICS to adjust default even-proportions assumptions arising from aggregation in the case of 'one- or multi-sectors to multi-sectors'. Also, a producer/purchaser dollar value adjustment was conducted because the IMPLAN data includes producer values, while CFS data are based on purchaser values which include transportation cost, wholesale markup, and retail markup besides the producer values.[1]

[1] After getting producer and purchaser value at BEA 5 digit level from BEA NDN-3007 data in 'www.bea.gov/bea/dn2/iedguide.htm/#IO', producer/purchaser ratio can be calibrated by aggregating the raw data to 2 digit SCTG sectors following <Figure-1> process.

<Figure-1> Data Reconciliation Process from IMPLAN Codes to SCTG codes




**< NOTE >**

*Bold: Bridge Code

1: Ind. = Industry, Comm.= (Commodity)

2: One =One sector, Multi. =Sectors more than one

3: (Merged) Data Status

4: Source and Abbreviation

BEA: Bureau of Economic Analysis (http://www.bea.doc.gov)

<Table-1> IMPLAN reconciliation with 1997/2002 CFS revised producer prices: U.S. Total

| **Sectors** | **2001 IMPLAN** | | **2002 CFS_Revised** | | **1997 CFS_Revised** | | **2002 Ratio** | | **1997 Ratio** | |
|---|---|---|---|---|---|---|---|---|---|---|
| USC | V1* | P1** | V4 | P4 | V5 | P5 | V1/ V4 | P1/ P4 | V1/ V5 | P1/ P5 |
| USC01 | 192,478 | 3.18% | 171,981 | 2.92% | 153,997 | 3.03% | 1.12 | 1.09 | 1.25 | 1.05 |
| USC02 | 130,536 | 2.16% | 131,504 | 2.24% | 115,470 | 2.27% | 0.99 | 0.97 | 1.13 | 0.95 |
| USC03 | 45,911 | 0.76% | 41,433 | 0.70% | 50,130 | 0.99% | 1.11 | 1.08 | 0.92 | 0.77 |
| USC04 | 86,329 | 1.43% | 86,226 | 1.47% | 79,122 | 1.56% | 1.00 | 0.97 | 1.09 | 0.92 |
| USC05 | 302,706 | 5.01% | 263,970 | 4.49% | 252,361 | 4.96% | 1.15 | 1.11 | 1.20 | 1.01 |
| USC06 | 80,602 | 1.33% | 76,558 | 1.30% | 58,148 | 1.14% | 1.05 | 1.02 | 1.39 | 1.17 |
| USC07 | 54,172 | 0.90% | 49,519 | 0.84% | 36,191 | 0.71% | 1.09 | 1.06 | 1.50 | 1.26 |
| USC08 | 20,141 | 0.33% | 19,396 | 0.33% | 17,936 | 0.35% | 1.04 | 1.01 | 1.12 | 0.94 |
| USC09 | 11,054 | 0.18% | 14,729 | 0.25% | 11,794 | 0.23% | 0.75 | 0.73 | 0.94 | 0.79 |
| USC10 | 480,173 | 7.94% | 270,347 | 4.60% | 253,304 | 4.98% | 1.78 | 1.73 | 1.90 | 1.59 |
| USC11 | 104,099 | 1.72% | 120,479 | 2.05% | 126,464 | 2.49% | 0.86 | 0.84 | 0.82 | 0.69 |
| USC12 | 174,086 | 2.88% | 300,630 | 5.11% | 158,114 | 3.11% | 0.58 | 0.56 | 1.10 | 0.93 |
| USC13 | 22,231 | 0.37% | 29,431 | 0.50% | 23,606 | 0.46% | 0.76 | 0.73 | 0.94 | 0.79 |
| USC14 | 159,819 | 2.64% | 172,452 | 2.93% | 154,153 | 3.03% | 0.93 | 0.90 | 1.04 | 0.87 |
| USC15 | 231,896 | 3.83% | 248,130 | 4.22% | 201,484 | 3.96% | 0.93 | 0.91 | 1.15 | 0.97 |
| USC16 | 122,282 | 2.02% | 115,614 | 1.97% | 113,525 | 2.23% | 1.06 | 1.03 | 1.08 | 0.91 |
| USC17 | 154,827 | 2.56% | 160,021 | 2.72% | 158,010 | 3.11% | 0.97 | 0.94 | 0.98 | 0.82 |
| USC18 | 133,501 | 2.21% | 106,600 | 1.81% | 202,729 | 3.99% | 1.25 | 1.22 | 0.66 | 0.55 |
| USC19 | 292,878 | 4.84% | 316,653 | 5.39% | 236,813 | 4.66% | 0.92 | 0.90 | 1.24 | 1.04 |
| USC20 | 113,064 | 1.87% | 114,330 | 1.94% | 87,240 | 1.72% | 0.99 | 0.96 | 1.30 | 1.09 |
| USC21 | 169,411 | 2.80% | 213,769 | 3.64% | 240,745 | 4.73% | 0.79 | 0.77 | 0.70 | 0.59 |
| USC22 | 200,391 | 3.31% | 199,880 | 3.40% | 193,294 | 3.80% | 1.00 | 0.97 | 1.04 | 0.87 |
| USC23 | 433,014 | 7.16% | 424,514 | 7.22% | 347,545 | 6.83% | 1.02 | 0.99 | 1.25 | 1.05 |
| USC24 | 844,544 | 13.96% | 799,929 | 13.60% | 733,800 | 14.43% | 1.06 | 1.03 | 1.15 | 0.97 |
| USC25 | 654,570 | 10.82% | 620,959 | 10.56% | 481,910 | 9.48% | 1.05 | 1.02 | 1.36 | 1.14 |
| USC26 | 143,113 | 2.37% | 157,354 | 2.68% | 124,723 | 2.45% | 0.91 | 0.88 | 1.15 | 0.96 |
| USC27 | 160,050 | 2.65% | 166,576 | 2.83% | 118,491 | 2.33% | 0.96 | 0.93 | 1.35 | 1.14 |
| USC28 | 92,277 | 1.53% | 82,582 | 1.40% | 59,471 | 1.17% | 1.12 | 1.09 | 1.55 | 1.30 |
| USC29 | 436,417 | 7.22% | 404,687 | 6.88% | 295,358 | 5.81% | 1.08 | 1.05 | 1.48 | 1.24 |
| ALL | 6,047,838 | 100% | 5,880,253 | 100% | 5,085,927 | 100% | 1.03 | 1.00 | 1.19 | 1.00 |

Another minor adjustment is required involving two of the SCTG sectors. One is CFS 'Mixed Freight' (SCTG 43), and the other is 'Oil and Gas Extraction' (SCTG 16). The CFS Mixed Freight sector has no comparable BEA commodity sectors (and IMPLAN) sectors. Going by the definition of the CFS Mixed Freight sector, we assumed that the value of SCTG 43 of 2002 CFS preliminary version can be the subsectors' value of wholesale, calculate subsectors ratio as 19.6 percent, and multiply the calculated ratio to Wholesale value of 2001 IMPLAN yielding $172 million as the producer value, which is close to $178 million calculated by the average of the 1987-1995 ratio of (gross margin/sales price= 20.7 percent) as 2002 SCTG 43 producer value (U.S. Bureau of the Census, 1997).[2]

Finally, in order to improve the correspondence of the IMPLAN sectors to SCTG sectors, we developed 29 USC sectors from the 43 SCTG sectors. During aggregation, 'Oil and Gas Extraction' sector was removed from CFS due to the problem of overwhelming number of shipments is included in USC sector 10, making bigger value than the revised CFS's. <Table-1> shows the final 2001 IMPLAN reconciliation with 1997 and 2002 CFS producer prices by USC Sector. 2001 IMPLAN value ratios with 2002 CFS (=V1/V4) in almost USC sectors are close to 1.[3]

# III. The Model

Estimated 2001 trade flows between U.S. states were develop via two models, from the original 1997 CFS by 29 USC Sectors, an Adjusted Flow Model (AFM) and a Double constrained Fratar Model (DFM). 1997 CFS includes unreported values in the total origin of state state $i$ and in the total destination of state $j$, in addition to the cell of trade flow between two states as shown <Appendix-B>. If those unreported values in 1997 CFS are adjusted for the first, therefore, 2001 trade flows can be estimated with Fratar model because 2001 IMPLAN support total origin and destination values by State. Excel Visual Basic program is used to those models.

## III-1. Adjusted Flow Model (AFM): To Adjust 1997 CFS Flows

To calculate each unreported cell of the trade flow between states, first, total origin and total destination values should be fixed. To calculate unreported Total Origin (Output) value of State $i$ (=$\boldsymbol{TO_i^*}$), we used the ratio of 2001 IMPLAN Total Origin of State $i$ ($ITO_i$) to the sum and 1997 CFS Reported Total Value of each USC sector $m$ (=$PTV_{USC\_m}$ ,$m$=1,…,29).[4] Similarly, Total Destination (Input) value of State $j$ (=$\boldsymbol{TD_j^*}$) is calibrated.

$$\boldsymbol{TO_i^*} = \left( \frac{ITO_i}{\sum_i ITO_i} \right) * PTV_{USC\_m}, \tag{1.}$$

[2] CFS 2002 preliminary version only reports for all U.S. without the content of each state.

[3] USC sector description and conversion table at 2 digit-level are suggested in <Appendix-A>.

[4] $ITO_i$ is denoted as Total supply commodity (consisting of Net Domstic Remains, Domestic Export, and Foreign Export) in IMPLAN plus *IFI*, because Foreign Imports should be counted in the trade flows in U.S. domestic trade or should be consumed in each State, once imports are done. Also, Foreign Imports more compactly related to region economy condition than Foreign Exports. $ITD_j$ is the sum of Net Domstic Remains, Domestic Imports and Adjusted Foreign Imports.

$$\boldsymbol{TD_j}^{*} = \left( \frac{ITD_j}{\sum_j ITD_j} \right) * PTV_{USC\_m} \qquad (2.)$$

From the estimated total origin/destination values, unreported trade flow values between state *ij* ($\boldsymbol{V_{ij}}^{*}$) can be filled in the matrix. In this computation, the cross-effects of origin and destination value are considered to estimate unreported cell value. For instance, the cell Computed from an Unreported Destination (=$\boldsymbol{CUD_{ij}}$) can get from unreported residual ($TD_j^{(*)} - \sum_{j'} V_{ij'}$) by multiplying the portion of total origin corresponding to unpublished cells sector $\boldsymbol{V_{ij}}^{*}$. See equation (3.) Similarly, a cell Computed from Unreported Origin (=$\boldsymbol{CUO_{ij}}$) is computed as in equation (4.)

$$\boldsymbol{CUD_{ij}} = \left( TD_j^{(*)} - \sum_{j'} V_{ij'} \right) * \left( \frac{TO_k^{(*)}}{\sum_k TO_k^{(*)}} \right). \qquad (3.)$$

$$\boldsymbol{CUO_{ij}} = \left( TO_i^{(*)} - \sum_{i'} V_{i'j} \right) * \left( \frac{TD_k^{(*)}}{\sum_k TD_k^{(*)}} \right) \qquad (4.)$$

$$\boldsymbol{V_{ij}}^{*} = \left( \frac{CUD_{ij} + CUO_{ij}}{2} \right) \qquad (5.)$$

where, indices *i'* and *j'* indicate only published cells and $V_{i,j'}$ or $V_{i',j}$ means only reported values or 0 of each cell in the matrix. Notation *k* indicates the corresponding cell in $\boldsymbol{TO_i}$ or $\boldsymbol{TD_j}$ to unreported cell $\boldsymbol{V_{ij}}^{*}$.

However, since two matrices ($\boldsymbol{CUD_{ij}}$ and $\boldsymbol{CUO_{ij}}$) are adjusted only based on total origin or total destination from the two equations of (3.) and (4.), by taking the mean value of the two in equation (5.), we can adjust one side effect to yield the estimated value of each cell.

To get optimal $\boldsymbol{V_{ij}}^{*}$, those equations (3.) to (5.) should be iterated as shown in (6.) to (8.)

$$\boldsymbol{CUD_{i\,j}}^{\boldsymbol{T}} = \left( TD_j^{T-1} - \sum_{j'} V_{j'}^{T-1} \right) * \left( \frac{TO_{j'}^{T-1}}{\sum_{j'} TO_{j'}^{T-1}} \right) \qquad (6.)$$

$$\boldsymbol{CUO_{i,j}}^{\boldsymbol{T}} = \left( TO_i^{T-1} - \sum_{i'} V_{i'}^{T-1} \right) * \left( \frac{TD_{i'}^{T-1}}{\sum_{i'} TD_{i'}^{T-1}} \right) \qquad (7.)$$

$$\boldsymbol{V_{ij}^{T}} = \left( \frac{CUD_{ij}^{T} + CUO_{ij}^{T}}{2} \right) \tag{8.}$$

Then, optimal value $\boldsymbol{V_{ij}^{T}}$ in $T^{th}$ iteration was chosen as the maximum value (= $MAX \sum_j \sum_i V_{ij}^{T}$ ) to satisfy the following criteria: Only if $\sum_j \sum_i V_{ij}^{T} \left( = \sum_i \sum_j V_{ij}^{T} \right)$ is equal or less than $PTV_{USC\_m}$, or $\sum_j \sum_i V_{ij}^{T-1} \left( = \sum_j \sum_i V_{ij}^{T} \right)$<0.99. Note that the optimal value $\boldsymbol{V_{ij}^{T}}$ from this model is the closest value to $PTV_{USC\_m}$, but considers only destination attraction and origin supply power, not distance effects.

### III-2. Double Constrained Fratar Model (DFM): To estimate 2001 Trade Flows

Each adjusted cell value by the AFM can be further adjusted to 2001 flow values of State *ij* ($\boldsymbol{FV_{ij}^{*}}$) by following the traditional Fratar Model.

$$\boldsymbol{FV_{ij}^{*}} = V_{ij}^{*} \times G_i \times G_j \times \left\{ \frac{(L_i + L_j)}{2} \right\} \tag{9.}$$

where, $\boldsymbol{FV_{ij}^{*}}$ is the cell value estimated by Fratar Model, $ETO_i$ and $ETD_j$ is estimated values $TO_i$ and $TD_j$ by Adjusted flow model, respectively. Since the Fratar Model is suitable only for calculating non-diagonal interregional cells, by letting $IND_{ii}$ be IMPLAN Net Domestic Remains plus *RIFI* (Remained IMPLAN Foreign Import) for each state, we can create the following variables for equation (9.):

$INTO_i = ITO_i - IFE_i$, $INTD_j = ITD_j - OIFI_i = ITD_j - OIFI_j'$,[5]

$Net\_INTO_i = INTO_i - IND_{ii}$, $Net\_INTD_j = INTD_j - IND_{ii}$,

$Net\_ETO_i = ETO_i - IND_{ii}$, $Net\_ETD_j = ETD_j - IND_{ii}$,

$G_i = Net\_INTO_i / Net\_ETO_i$, $G_j = Net\_INTD_j / Net\_ETD_j$, and hence,

$L_i = \frac{NET\_ETO_i}{\sum_j (V_{ij}^{*} \times G_j)}$, $L_j = \frac{NET\_ETD_j}{\sum_i (V_{ij}^{*} \times G_i)}$.

[5] We did not count Foreign Exprots for estimating each trade flow in the concept $INTO_i$ and $INTD_j$. The reason is that Foreign Export data in IMPLAN means Foreign Exports of each State and therefore the relation between other industries might be juggled in constructing NIEMO when including Foreign Exports, because 1) they cannot separate which amount directly goes to Rest of World from each State and which amount goes to outbound and then to the Rest of World and 2) economically those are only related to the industry of Transportation Service. Therefore, it is better to leave Foreign Exports as its own region.

Because Foreign Imports should be considered for each state, Estimated Diagonal Value ($\mathbf{DV_{ii}^{*}}$) meaning the estimated trade flow within each state can be calculated by the following equation (10.) and substitute only diagonal values $IND_{ii}$ if and only if $\mathbf{DV_{ii}^{*}} > IND_{ii}$.

$$\boldsymbol{DV_{ii}^{*}} = V_{ii}^{*} \times DG_i \times DG_j \times \left\{ \frac{(DL_i + DL_j)}{2} \right\} \qquad (10.)$$

where, $DG_i = ITO_i / ETO_i$, $DG_j = ITD_j / ETD_j$,

$$DL_i = \frac{ETO_i}{\sum_j (V_{ij}^{*} \times G_j)},\ DL_j = \frac{ETD_j}{\sum_i (V_{ij}^{*} \times G_i)}.$$

During iterations shown in equations (11.), since $\boldsymbol{FV_{ij}^{T}}$ meaning $T^{th}$ iterated non-diagonal values are affected by substituted $\boldsymbol{DV_{ij}^{T}}$ (=$IND_{ii}^{T}$) meaning the $T^{th}$ iterated diagonal value, that is the Independent Fratar Model for $\boldsymbol{DV_{ij}^{T-1}}$ with diagonal values is related to another Fratar Model for $\boldsymbol{FV_{ij}^{T}}$ without diagonal values, we label these two models as the DFM. Therefore, $\boldsymbol{FV_{ij}^{T}}$ by DFM can be an optimally adjusted value considering each diagonal value.

$$\boldsymbol{FV_{ij}^{T}} = FV_{ij}^{T-1} \times G_i^{T-1} \times G_j^{T-1} \times \left\{ \frac{(L_i^{T-1} + L_j^{T-1})}{2} \right\} \qquad (11.)$$

$$\boldsymbol{DV_{ij}^{T}} = DV_{ii}^{T-1} \times DG_i^{T-1} \times DG_j^{T-1} \times \left\{ \frac{(DL_i^{T-1} + DL_j^{T-1})}{2} \right\} \qquad (12.)$$

where, $\boldsymbol{DV_{ij}^{T}}$ will substitute $IND_{ii}^{T-1}$ repetedly if and only if $\boldsymbol{DV_{ij}^{T}} > IND_{ii}^{T-1}$ and $T$=1.

The stopping rule to get optimal value of $\boldsymbol{FV_{ij}^{T}}$ from equations (11.) is bounded to Maximum $\boldsymbol{FV_{ij}^{T}}$(=$MAX$ $\boldsymbol{FV_{ij}^{T}}$) . The $MAX$ $\boldsymbol{FV_{ij}^{T}}$ is chosen when satisfying the following two conditions:

a. 0.999 <($Net\_ITO_i$ / $\boldsymbol{FV_{ij}^{T}}$ ) < 1.001 and 0.999 <($Net\_ITD_i$ / $\boldsymbol{FV_{ij}^{T}}$ ) < 1.001, Or

b. 0.999 <( $\boldsymbol{FV_{ij}^{T-1}}$ / $\boldsymbol{FV_{ij}^{T}}$) < 1.001.

In the next section, we will suggest examples estimated by each model from raw 1997 CFS flows between states for USC Sector 15 (Plastics and Rubber) corresponding to SCTG 24 shown in <Appendix-B>.

<Table-2> 1997 Estimated Trade Flows between U.S. States by Adjusted Flow Model

| | AL | AK | AZ | AR | CA | CO | CT | DE | DC | FL | GA | HI | ID | IL | IN | IA | KS | KY | LA | ME | MD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alabama** | 824 | 0 | 28 | 47 | 220 | 20 | 27 | 21 | 0 | 201 | 305 | 2 | 6 | 154 | 75 | 25 | 28 | 100 | 42 | 8 | 28 |
| **Alaska** | 0 | 77 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Arizona** | 11 | 0 | 1014 | 19 | 284 | 25 | 11 | 8 | 0 | 9 | 18 | 1 | 4 | 56 | 9 | 1 | 3 | 23 | 7 | 3 | 4 |
| **Arkansas** | 27 | 1 | 23 | 785 | 140 | 21 | 22 | 17 | 0 | 108 | 162 | 0 | 5 | 115 | 128 | 20 | 23 | 80 | 63 | 7 | 23 |
| **California** | 76 | 3 | 610 | 104 | 12557 | 228 | 92 | 7 | 3 | 297 | 148 | 66 | 80 | 416 | 206 | 52 | 53 | 66 | 38 | 28 | 40 |
| **Colorado** | 15 | 0 | 14 | 11 | 107 | 977 | 14 | 11 | 0 | 13 | 26 | 1 | 3 | 42 | 5 | 13 | 14 | 30 | 10 | 4 | 6 |
| **Connecticut** | 6 | 1 | 22 | 6 | 262 | 16 | 484 | 16 | 1 | 87 | 61 | 1 | 0 | 53 | 44 | 20 | 22 | 20 | 8 | 11 | 5 |
| **Delaware** | 7 | 0 | 6 | 11 | 53 | 5 | 6 | 14 | 0 | 25 | 24 | 0 | 1 | 6 | 19 | 6 | 6 | 13 | 5 | 2 | 65 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| **Florida** | 109 | 1 | 19 | 24 | 122 | 17 | 15 | 32 | 1 | 4234 | 260 | 2 | 8 | 105 | 70 | 15 | 19 | 60 | 25 | 11 | 24 |
| **Georgia** | 475 | 4 | 65 | 152 | 359 | 19 | 44 | 26 | 3 | 785 | 3085 | 8 | 22 | 259 | 73 | 34 | 13 | 82 | 98 | 29 | 59 |
| **Hawaii** | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Idaho** | 3 | 0 | 3 | 6 | 44 | 2 | 3 | 3 | 0 | 6 | 6 | 0 | 242 | 18 | 14 | 3 | 3 | 7 | 2 | 0 | 3 |
| **Illinois** | 106 | 9 | 82 | 105 | 777 | 50 | 225 | 165 | 8 | 212 | 753 | 19 | 54 | 6895 | 911 | 427 | 201 | 474 | 61 | 72 | 563 |
| **Indiana** | 49 | 2 | 23 | 73 | 157 | 27 | 26 | 26 | 2 | 118 | 189 | 0 | 11 | 750 | 2129 | 118 | 71 | 336 | 19 | 26 | 34 |
| **Iowa** | 31 | 1 | 9 | 34 | 101 | 11 | 29 | 22 | 0 | 29 | 108 | 0 | 4 | 319 | 153 | 813 | 66 | 164 | 37 | 8 | 7 |
| **Kansas** | 25 | 0 | 18 | 59 | 207 | 89 | 1 | 2 | 1 | 36 | 59 | 0 | 5 | 154 | 158 | 59 | 750 | 28 | 17 | 7 | 24 |
| **Kentucky** | 77 | 1 | 7 | 85 | 102 | 9 | 23 | 24 | 1 | 93 | 249 | 2 | 6 | 197 | 274 | 28 | 48 | 865 | 37 | 9 | 31 |
| **Louisiana** | 254 | 2 | 15 | 350 | 241 | 12 | 52 | 40 | 0 | 114 | 134 | 0 | 11 | 333 | 173 | 162 | 22 | 286 | 1386 | 15 | 6 |
| **Maine** | 4 | 0 | 4 | 6 | 27 | 3 | 9 | 0 | 0 | 8 | 8 | 0 | 1 | 29 | 15 | 3 | 4 | 8 | 3 | 135 | 4 |
| **Maryland** | 15 | 0 | 14 | 25 | 92 | 10 | 4 | 49 | 59 | 25 | 8 | 0 | 3 | 50 | 60 | 13 | 1 | 6 | 10 | 4 | 798 |
| **Massachusetts** | 10 | 2 | 62 | 22 | 225 | 16 | 214 | 44 | 2 | 68 | 112 | 5 | 14 | 214 | 121 | 7 | 21 | 51 | 8 | 235 | 88 |
| **Michigan** | 39 | 0 | 74 | 113 | 383 | 46 | 9 | 51 | 2 | 143 | 248 | 4 | 13 | 382 | 593 | 33 | 36 | 125 | 46 | 18 | 62 |
| **Minnesota** | 9 | 0 | 36 | 11 | 269 | 75 | 18 | 29 | 1 | 56 | 49 | 3 | 8 | 326 | 179 | 167 | 29 | 82 | 28 | 12 | 22 |
| **Mississippi** | 66 | 1 | 31 | 33 | 125 | 8 | 29 | 21 | 0 | 75 | 197 | 2 | 0 | 166 | 88 | 15 | 30 | 42 | 75 | 9 | 3 |
| **Missouri** | 35 | 1 | 5 | 101 | 88 | 21 | 5 | 23 | 1 | 62 | 111 | 2 | 6 | 380 | 87 | 93 | 164 | 63 | 21 | 9 | 26 |
| **Montana** | 1 | 0 | 1 | 2 | 5 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 0 | 4 | 0 | 1 | 1 | 0 | 1 | 0 | 1 |
| **Nebraska** | 6 | 0 | 5 | 17 | 37 | 8 | 10 | 8 | 0 | 25 | 11 | 0 | 10 | 76 | 41 | 95 | 16 | 52 | 7 | 3 | 11 |
| **Nevada** | 3 | 0 | 19 | 5 | 251 | 8 | 3 | 2 | 0 | 5 | 4 | 0 | 7 | 1 | 13 | 2 | 3 | 6 | 2 | 1 | 3 |
| **New Hampshire** | 12 | 0 | 11 | 17 | 72 | 0 | 10 | 8 | 0 | 23 | 25 | 1 | 0 | 57 | 43 | 10 | 11 | 22 | 8 | 3 | 11 |
| **New Jersey** | 74 | 5 | 128 | 57 | 611 | 71 | 243 | 90 | 4 | 284 | 181 | 9 | 28 | 356 | 199 | 23 | 98 | 141 | 41 | 29 | 404 |
| **New Mexico** | 0 | 0 | 2 | 3 | 18 | 11 | 2 | 0 | 0 | 3 | 3 | 0 | 0 | 9 | 8 | 1 | 2 | 0 | 1 | 0 | 2 |
| **New York** | 49 | 2 | 70 | 36 | 617 | 15 | 248 | 31 | 2 | 136 | 112 | 3 | 14 | 272 | 192 | 15 | 5 | 38 | 17 | 20 | 117 |
| **North Carolina** | 132 | 0 | 55 | 50 | 422 | 17 | 58 | 79 | 3 | 286 | 787 | 7 | 21 | 184 | 88 | 26 | 32 | 195 | 37 | 15 | 156 |
| **North Dakota** | 1 | 0 | 1 | 2 | 7 | 3 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 5 | 4 | 1 | 3 | 1 | 0 | 1 |
| **Ohio** | 301 | 5 | 152 | 174 | 609 | 80 | 93 | 49 | 4 | 366 | 710 | 9 | 18 | 924 | 935 | 231 | 166 | 714 | 55 | 39 | 190 |
| **Oklahoma** | 12 | 1 | 28 | 45 | 241 | 34 | 6 | 16 | 1 | 70 | 150 | 1 | 4 | 155 | 82 | 19 | 58 | 13 | 10 | 6 | 24 |
| **Oregon** | 1 | 0 | 11 | 20 | 280 | 18 | 12 | 9 | 0 | 4 | 7 | 1 | 39 | 12 | 50 | 10 | 12 | 25 | 7 | 3 | 11 |
| **Pennsylvania** | 123 | 13 | 48 | 51 | 686 | 42 | 153 | 188 | 17 | 340 | 265 | 27 | 26 | 400 | 693 | 128 | 109 | 105 | 83 | 24 | 391 |
| **Rhode Island** | 13 | 0 | 11 | 10 | 80 | 1 | 26 | 8 | 0 | 4 | 31 | 0 | 3 | 21 | 42 | 11 | 11 | 1 | 9 | 3 | 5 |
| **South Carolina** | 126 | 1 | 31 | 23 | 115 | 29 | 30 | 90 | 0 | 99 | 446 | 3 | 8 | 192 | 48 | 5 | 42 | 114 | 28 | 56 | 41 |
| **South Dakota** | 4 | 0 | 3 | 6 | 16 | 2 | 3 | 0 | 0 | 10 | 8 | 0 | 1 | 7 | 16 | 7 | 3 | 7 | 2 | 1 | 4 |
| **Tennessee** | 249 | 5 | 35 | 213 | 283 | 155 | 114 | 82 | 0 | 166 | 1152 | 0 | 29 | 370 | 144 | 111 | 36 | 267 | 103 | 50 | 41 |
| **Texas** | 300 | 5 | 180 | 492 | 1820 | 322 | 47 | 141 | 0 | 411 | 986 | 10 | 27 | 1292 | 659 | 214 | 262 | 278 | 282 | 50 | 91 |
| **Utah** | 6 | 0 | 16 | 10 | 123 | 4 | 6 | 0 | 0 | 4 | 9 | 0 | 65 | 14 | 25 | 3 | 4 | 12 | 3 | 2 | 5 |
| **Vermont** | 3 | 0 | 3 | 5 | 5 | 2 | 6 | 2 | 0 | 5 | 6 | 0 | 1 | 2 | 11 | 2 | 3 | 6 | 2 | 1 | 3 |
| **Virginia** | 63 | 2 | 10 | 21 | 200 | 39 | 24 | 40 | 2 | 83 | 259 | 4 | 13 | 160 | 98 | 53 | 54 | 156 | 42 | 17 | 172 |
| **Washington** | 18 | 34 | 28 | 32 | 330 | 7 | 18 | 0 | 0 | 32 | 17 | 6 | 87 | 43 | 78 | 15 | 15 | 39 | 11 | 5 | 17 |
| **West Virginia** | 25 | 0 | 23 | 36 | 154 | 17 | 22 | 16 | 0 | 5 | 18 | 0 | 5 | 122 | 89 | 21 | 22 | 29 | 16 | 7 | 24 |
| **Wisconsin** | 30 | 3 | 49 | 93 | 507 | 44 | 85 | 63 | 3 | 141 | 110 | 7 | 8 | 864 | 282 | 115 | 46 | 99 | 34 | 27 | 62 |
| **Wyoming** | 2 | 0 | 0 | 0 | 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 7 | 2 | 2 | 4 | 0 | 0 | 0 |
| *TDi* | 3809 | 148 | 3106 | 3775 | 24374 | 2632 | 2596 | 1715 | 113 | 9291 | 11559 | 320 | 830 | 16948 | 9600 | 3233 | 2687 | 5384 | 2803 | 1004 | 3710 |
| *? ¡Vij* | 3826 | 182 | 3105 | 3601 | 24451 | 2636 | 2582 | 1574 | 121 | 9312 | 11621 | 394 | 922 | 16968 | 9434 | 3252 | 2641 | 5335 | 2846 | 1022 | 3720 |
| (? ¡Vij)/TDj | 1.005 | 1.227 | 1.000 | 0.954 | 1.003 | 1.001 | 0.995 | 0.918 | 1.075 | 1.002 | 1.005 | 1.230 | 1.111 | 1.001 | 0.983 | 1.006 | 0.983 | 0.991 | 1.015 | 1.018 | 1.003 |

*(Continued)*

| | MA | MI | MN | MS | MO | MT | NE | NV | NH | NJ | NM | NY | NC | ND | OH | OK | OR | PA | RI | SC | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alabama** | 16 | 30 | 41 | 45 | 74 | 5 | 14 | 9 | 14 | 69 | 4 | 98 | 74 | 5 | 393 | 18 | 19 | 149 | 11 | 48 | 3 |
| **Alaska** | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Arizona** | 4 | 39 | 15 | 11 | 14 | 2 | 5 | 25 | 5 | 24 | 26 | 10 | 5 | 2 | 8 | 5 | 21 | 26 | 1 | 20 | 1 |
| **Arkansas** | 9 | 78 | 18 | 41 | 64 | 4 | 11 | 7 | 11 | 46 | 4 | 29 | 102 | 4 | 95 | 140 | 16 | 63 | 9 | 114 | 3 |
| **California** | 86 | 163 | 128 | 67 | 129 | 30 | 49 | 247 | 54 | 265 | 32 | 322 | 303 | 18 | 312 | 58 | 395 | 200 | 43 | 26 | 8 |
| **Colorado** | 14 | 7 | 37 | 1 | 19 | 3 | 7 | 4 | 7 | 26 | 16 | 14 | 7 | 3 | 56 | 6 | 4 | 40 | 6 | 27 | 2 |
| **Connecticut** | 204 | 31 | 33 | 22 | 11 | 4 | 8 | 7 | 84 | 232 | 4 | 321 | 118 | 4 | 88 | 15 | 16 | 77 | 8 | 6 | 3 |
| **Delaware** | 39 | 26 | 10 | 9 | 10 | 1 | 0 | 2 | 3 | 108 | 1 | 64 | 21 | 0 | 44 | 4 | 7 | 37 | 21 | 12 | 0 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Florida** | 36 | 89 | 25 | 23 | 38 | 7 | 15 | 2 | 4 | 98 | 1 | 112 | 81 | 7 | 118 | 27 | 27 | 108 | 2 | 59 | 5 |
| **Georgia** | 57 | 223 | 156 | 152 | 108 | 17 | 11 | 10 | 47 | 78 | 17 | 82 | 497 | 19 | 387 | 33 | 12 | 197 | 36 | 444 | 13 |
| **Hawaii** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Idaho** | 8 | 12 | 5 | 3 | 4 | 7 | 0 | 1 | 2 | 8 | 0 | 19 | 8 | 1 | 12 | 2 | 22 | 8 | 0 | 6 | 0 |
| **Illinois** | 172 | 1463 | 544 | 88 | 599 | 19 | 208 | 76 | 11 | 534 | 12 | 374 | 330 | 50 | 1140 | 139 | 57 | 629 | 88 | 67 | 42 |
| **Indiana** | 50 | 648 | 99 | 21 | 281 | 10 | 78 | 22 | 4 | 91 | 9 | 154 | 129 | 10 | 712 | 32 | 7 | 205 | 21 | 104 | 6 |
| **Iowa** | 18 | 228 | 223 | 32 | 285 | 21 | 133 | 9 | 14 | 35 | 5 | 64 | 96 | 73 | 177 | 26 | 34 | 82 | 11 | 29 | 55 |
| **Kansas** | 7 | 82 | 48 | 24 | 241 | 4 | 81 | 7 | 12 | 70 | 4 | 130 | 31 | 4 | 75 | 58 | 13 | 82 | 9 | 53 | 3 |
| **Kentucky** | 76 | 297 | 36 | 61 | 64 | 6 | 2 | 8 | 1 | 136 | 5 | 63 | 107 | 6 | 378 | 14 | 6 | 124 | 0 | 59 | 4 |
| **Louisiana** | 62 | 205 | 74 | 258 | 50 | 9 | 27 | 16 | 26 | 123 | 8 | 180 | 235 | 37 | 219 | 215 | 17 | 190 | 21 | 88 | 6 |
| **Maine** | 36 | 13 | 6 | 4 | 5 | 1 | 0 | 1 | 12 | 10 | 0 | 20 | 9 | 0 | 8 | 2 | 0 | 6 | 1 | 7 | 0 |
| **Maryland** | 66 | 35 | 21 | 15 | 11 | 3 | 7 | 0 | 7 | 98 | 2 | 160 | 34 | 3 | 41 | 9 | 10 | 199 | 6 | 10 | 0 |
| **Massachusetts** | 2080 | 116 | 68 | 28 | 50 | 11 | 32 | 20 | 30 | 338 | 11 | 610 | 192 | 12 | 263 | 9 | 13 | 191 | 161 | 119 | 8 |
| **Michigan** | 93 | 4766 | 106 | 18 | 270 | 12 | 20 | 20 | 20 | 89 | 10 | 74 | 130 | 3 | 818 | 26 | 45 | 172 | 2 | 37 | 8 |
| **Minnesota** | 95 | 115 | 2019 | 40 | 157 | 9 | 107 | 5 | 19 | 83 | 6 | 64 | 101 | 57 | 43 | 27 | 29 | 75 | 15 | 7 | 61 |
| **Mississippi** | 26 | 35 | 49 | 668 | 43 | 5 | 59 | 10 | 15 | 41 | 5 | 33 | 68 | 6 | 200 | 21 | 23 | 62 | 11 | 16 | 0 |
| **Missouri** | 18 | 169 | 71 | 31 | 1482 | 5 | 40 | 1 | 6 | 21 | 5 | 169 | 33 | 6 | 133 | 91 | 80 | 65 | 12 | 44 | 7 |
| **Montana** | 2 | 3 | 1 | 1 | 1 | 87 | 0 | 0 | 0 | 2 | 0 | 5 | 2 | 0 | 1 | 0 | 1 | 2 | 0 | 2 | 0 |
| **Nebraska** | 10 | 73 | 35 | 2 | 58 | 2 | 246 | 3 | 5 | 27 | 2 | 24 | 13 | 2 | 48 | 4 | 3 | 45 | 0 | 20 | 14 |
| **Nevada** | 7 | 10 | 4 | 3 | 3 | 1 | 1 | 146 | 1 | 6 | 1 | 17 | 6 | 0 | 9 | 2 | 14 | 6 | 1 | 0 | 0 |
| **New Hampshire** | 25 | 42 | 16 | 11 | 16 | 2 | 1 | 3 | 265 | 20 | 0 | 92 | 27 | 0 | 44 | 7 | 8 | 15 | 12 | 20 | 1 |
| **New Jersey** | 518 | 168 | 197 | 49 | 157 | 22 | 65 | 40 | 61 | 3689 | 22 | 1844 | 480 | 24 | 522 | 18 | 95 | 902 | 48 | 244 | 16 |
| **New Mexico** | 4 | 6 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 4 | 197 | 10 | 4 | 0 | 6 | 0 | 1 | 4 | 1 | 0 | 0 |
| **New York** | 178 | 322 | 113 | 16 | 169 | 5 | 35 | 21 | 63 | 851 | 11 | 3489 | 181 | 13 | 515 | 5 | 48 | 1022 | 17 | 132 | 8 |
| **North Carolina** | 229 | 239 | 102 | 47 | 189 | 1 | 23 | 31 | 47 | 165 | 17 | 523 | 3294 | 18 | 474 | 64 | 82 | 313 | 37 | 1024 | 12 |
| **North Dakota** | 3 | 4 | 29 | 1 | 2 | 15 | 1 | 0 | 0 | 3 | 0 | 7 | 3 | 114 | 4 | 1 | 1 | 3 | 0 | 0 | 0 |
| **Ohio** | 255 | 1436 | 258 | 114 | 344 | 10 | 66 | 36 | 25 | 525 | 23 | 778 | 671 | 12 | 5821 | 85 | 154 | 958 | 57 | 216 | 20 |
| **Oklahoma** | 8 | 143 | 32 | 22 | 105 | 4 | 11 | 7 | 10 | 36 | 3 | 69 | 18 | 4 | 155 | 456 | 33 | 76 | 8 | 41 | 3 |
| **Oregon** | 29 | 5 | 9 | 12 | 12 | 23 | 6 | 7 | 6 | 26 | 1 | 4 | 4 | 2 | 39 | 7 | 830 | 12 | 5 | 21 | 1 |
| **Pennsylvania** | 289 | 434 | 138 | 80 | 144 | 52 | 34 | 98 | 62 | 985 | 6 | 881 | 372 | 13 | 760 | 47 | 57 | 3970 | 61 | 95 | 6 |
| **Rhode Island** | 25 | 47 | 1 | 11 | 3 | 2 | 6 | 4 | 13 | 51 | 2 | 57 | 31 | 0 | 21 | 8 | 9 | 34 | 4 | 22 | 1 |
| **South Carolina** | 51 | 197 | 61 | 48 | 57 | 7 | 10 | 13 | 56 | 67 | 6 | 190 | 680 | 7 | 290 | 27 | 28 | 124 | 6 | 1893 | 5 |
| **South Dakota** | 1 | 21 | 5 | 0 | 10 | 2 | 11 | 1 | 2 | 9 | 1 | 13 | 8 | 1 | 14 | 2 | 2 | 6 | 1 | 8 | 121 |
| **Tennessee** | 269 | 635 | 100 | 206 | 155 | 21 | 25 | 15 | 14 | 155 | 22 | 313 | 225 | 23 | 520 | 37 | 96 | 227 | 54 | 208 | 16 |
| **Texas** | 183 | 790 | 201 | 280 | 405 | 69 | 122 | 138 | 53 | 503 | 207 | 382 | 628 | 32 | 987 | 456 | 166 | 674 | 51 | 375 | 20 |
| **Utah** | 15 | 7 | 5 | 6 | 7 | 7 | 3 | 13 | 3 | 13 | 3 | 7 | 3 | 1 | 13 | 3 | 20 | 3 | 0 | 11 | 1 |
| **Vermont** | 55 | 2 | 3 | 2 | 4 | 0 | 0 | 1 | 14 | 13 | 0 | 53 | 6 | 0 | 23 | 2 | 2 | 27 | 1 | 5 | 0 |
| **Virginia** | 96 | 191 | 27 | 7 | 57 | 10 | 4 | 18 | 67 | 283 | 10 | 263 | 243 | 11 | 423 | 11 | 42 | 317 | 21 | 135 | 5 |
| **Washington** | 10 | 6 | 25 | 6 | 23 | 3 | 7 | 10 | 9 | 16 | 3 | 14 | 10 | 3 | 40 | 11 | 294 | 25 | 7 | 34 | 2 |
| **West Virginia** | 53 | 128 | 35 | 23 | 35 | 4 | 0 | 0 | 11 | 60 | 4 | 120 | 36 | 0 | 232 | 0 | 17 | 166 | 0 | 43 | 0 |
| **Wisconsin** | 44 | 470 | 463 | 89 | 108 | 16 | 44 | 9 | 43 | 107 | 16 | 466 | 102 | 21 | 422 | 62 | 11 | 185 | 33 | 46 | 12 |
| **Wyoming** | 0 | 8 | 3 | 0 | 3 | 0 | 1 | 0 | 0 | 5 | 0 | 9 | 0 | 0 | 8 | 1 | 1 | 0 | 0 | 4 | 0 |
| *TDi* | 5731 | 14241 | 5610 | 2743 | 6054 | 530 | 1639 | 1026 | 1312 | 10216 | 670 | 13047 | 9723 | 626 | 17050 | 2281 | 2752 | 12099 | 1001 | 6025 | 470 |
| *? ¡Vij* | 5631 | 14259 | 5700 | 2699 | 6077 | 561 | 1637 | 1124 | 1238 | 10243 | 744 | 12805 | 9788 | 630 | 17111 | 2295 | 2886 | 12104 | 921 | 6001 | 502 |
| (? ¡Vij)/TDj | 0.983 | 1.001 | 1.016 | 0.984 | 1.004 | 1.058 | 0.999 | 1.095 | 0.944 | 1.003 | 1.111 | 0.981 | 1.007 | 1.006 | 1.004 | 1.006 | 1.049 | 1.000 | 0.920 | 0.996 | 1.069 |

*(Continued)*

| | TN | TX | UT | VM | VA | WA | WV | WI | WY | *TOi* | ? $_i$*Vij* | (? $_i$Vij)/TOi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alabama** | 205 | 326 | 18 | 5 | 22 | 4 | 14 | 19 | 4 | 3869 | 3914 | 1.012 |
| **Alaska** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 79 | 84 | 1.069 |
| **Arizona** | 4 | 51 | 7 | 2 | 35 | 15 | 5 | 11 | 1 | 1789 | 1908 | 1.067 |
| **Arkansas** | 79 | 355 | 15 | 1 | 3 | 15 | 11 | 19 | 3 | 3114 | 3138 | 1.008 |
| **California** | 119 | 699 | 204 | 7 | 67 | 585 | 5 | 141 | 21 | 19867 | 19953 | 1.004 |
| **Colorado** | 40 | 91 | 41 | 3 | 43 | 34 | 0 | 23 | 27 | 1911 | 1924 | 1.007 |
| **Connecticut** | 61 | 68 | 14 | 47 | 64 | 23 | 11 | 34 | 3 | 2768 | 2765 | 0.999 |
| **Delaware** | 8 | 29 | 0 | 1 | 19 | 4 | 3 | 30 | 0 | 791 | 788 | 0.997 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 77 | 40 | 0.512 |
| **Florida** | 59 | 191 | 28 | 8 | 32 | 21 | 4 | 23 | 0 | 6385 | 6423 | 1.006 |
| **Georgia** | 434 | 407 | 31 | 0 | 108 | 24 | 51 | 179 | 12 | 9658 | 9536 | 0.987 |
| **Hawaii** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 188 | 201 | 1.071 |
| **Idaho** | 10 | 11 | 49 | 1 | 11 | 36 | 0 | 5 | 5 | 557 | 626 | 1.123 |
| **Illinois** | 319 | 1451 | 85 | 49 | 127 | 146 | 126 | 896 | 30 | 22300 | 22039 | 0.988 |
| **Indiana** | 180 | 285 | 36 | 10 | 167 | 40 | 15 | 224 | 7 | 7732 | 7843 | 1.014 |
| **Iowa** | 72 | 194 | 6 | 6 | 55 | 54 | 3 | 185 | 4 | 4148 | 4175 | 1.006 |
| **Kansas** | 35 | 277 | 24 | 5 | 11 | 25 | 7 | 49 | 4 | 3140 | 3173 | 1.011 |
| **Kentucky** | 379 | 327 | 21 | 6 | 64 | 12 | 11 | 46 | 0 | 4436 | 4486 | 1.011 |
| **Louisiana** | 289 | 967 | 35 | 10 | 192 | 55 | 26 | 121 | 7 | 7343 | 7377 | 1.005 |
| **Maine** | 10 | 21 | 2 | 1 | 11 | 4 | 0 | 14 | 0 | 479 | 477 | 0.995 |
| **Maryland** | 41 | 32 | 10 | 3 | 148 | 3 | 7 | 22 | 2 | 2165 | 2248 | 1.039 |
| **Massachusetts** | 146 | 291 | 8 | 123 | 85 | 34 | 32 | 85 | 8 | 6765 | 6713 | 0.992 |
| **Michigan** | 208 | 335 | 9 | 12 | 68 | 66 | 5 | 135 | 9 | 9923 | 10005 | 1.008 |
| **Minnesota** | 45 | 146 | 26 | 8 | 22 | 35 | 20 | 242 | 5 | 5073 | 5094 | 1.004 |
| **Mississippi** | 143 | 176 | 1 | 6 | 32 | 16 | 16 | 55 | 4 | 2993 | 2862 | 0.956 |
| **Missouri** | 132 | 305 | 10 | 6 | 93 | 35 | 15 | 55 | 0 | 4329 | 4442 | 1.026 |
| **Montana** | 2 | 4 | 1 | 0 | 3 | 1 | 0 | 1 | 16 | 143 | 159 | 1.115 |
| **Nebraska** | 29 | 32 | 7 | 0 | 30 | 11 | 5 | 48 | 1 | 1231 | 1237 | 1.005 |
| **Nevada** | 8 | 13 | 13 | 0 | 10 | 17 | 1 | 4 | 0 | 554 | 646 | 1.166 |
| **New Hampshire** | 5 | 62 | 7 | 100 | 31 | 12 | 5 | 9 | 0 | 1284 | 1201 | 0.935 |
| **New Jersey** | 165 | 647 | 35 | 28 | 225 | 74 | 17 | 108 | 16 | 13705 | 13574 | 0.990 |
| **New Mexico** | 5 | 33 | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 311 | 350 | 1.126 |
| **New York** | 89 | 599 | 24 | 45 | 142 | 74 | 20 | 148 | 9 | 10325 | 10376 | 1.005 |
| **North Carolina** | 541 | 299 | 32 | 15 | 479 | 110 | 93 | 85 | 13 | 11207 | 11250 | 1.004 |
| **North Dakota** | 3 | 6 | 1 | 0 | 4 | 1 | 1 | 2 | 0 | 216 | 247 | 1.142 |
| **Ohio** | 524 | 864 | 43 | 28 | 261 | 110 | 544 | 354 | 18 | 20427 | 20434 | 1.000 |
| **Oklahoma** | 45 | 292 | 8 | 4 | 13 | 34 | 11 | 149 | 3 | 2775 | 2779 | 1.001 |
| **Oregon** | 7 | 35 | 8 | 2 | 38 | 443 | 5 | 17 | 2 | 1978 | 2150 | 1.087 |
| **Pennsylvania** | 240 | 422 | 30 | 19 | 244 | 51 | 125 | 164 | 36 | 14060 | 13827 | 0.983 |
| **Rhode Island** | 30 | 20 | 7 | 2 | 29 | 14 | 0 | 21 | 0 | 953 | 766 | 0.804 |
| **South Carolina** | 119 | 248 | 27 | 23 | 109 | 41 | 20 | 85 | 5 | 6012 | 6027 | 1.003 |
| **South Dakota** | 9 | 21 | 2 | 0 | 10 | 4 | 2 | 6 | 7 | 412 | 400 | 0.971 |
| **Tennessee** | 1669 | 540 | 31 | 3 | 314 | 112 | 17 | 128 | 15 | 9947 | 9771 | 0.982 |
| **Texas** | 588 | 13169 | 120 | 33 | 373 | 229 | 88 | 210 | 24 | 29313 | 29425 | 1.004 |
| **Utah** | 1 | 36 | 545 | 1 | 5 | 22 | 3 | 7 | 4 | 1014 | 1078 | 1.063 |
| **Vermont** | 7 | 9 | 2 | 74 | 8 | 3 | 1 | 4 | 0 | 377 | 388 | 1.028 |
| **Virginia** | 155 | 254 | 37 | 11 | 1524 | 26 | 52 | 95 | 7 | 6007 | 5915 | 0.985 |
| **Washington** | 52 | 36 | 49 | 3 | 6 | 1749 | 8 | 26 | 2 | 3126 | 3323 | 1.063 |
| **West Virginia** | 23 | 135 | 15 | 0 | 60 | 97 | 485 | 19 | 0 | 2582 | 2449 | 0.949 |
| **Wisconsin** | 199 | 267 | 33 | 18 | 129 | 86 | 47 | 2444 | 11 | 8769 | 8677 | 0.989 |
| **Wyoming** | 5 | 12 | 1 | 0 | 5 | 0 | 1 | 3 | 0 | 155 | 113 | 0.726 |
| *TDi* | 7608 | 24996 | 1825 | 703 | 5812 | 4507 | 1832 | 6713 | 352 | | **278797** | |
| ? $_i$*Vij* | 7539 | 25091 | 1760 | 729 | 5530 | 4608 | 1938 | 6752 | 349 | **278797** | | |
| (? $_i$Vij)/TDj | 0.991 | 1.004 | 0.964 | 1.036 | 0.951 | 1.023 | 1.058 | 1.006 | 0.992 | | | |

**< NOTE >**

-V=Value (Mil $)

Notation

-*TOi*= Total Origin (Output) value of State *i*

<Table-3> Estimated Trade Flows between U.S. States for 2001 by Double Constrained Fratar Model

| | AL | AK | AZ | AR | CA | CO | CT | DE | DC | FL | GA | HI | ID | IL | IN | IA | KS | KY | LA | ME | MD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alabama** | 1501 | 0 | 27 | 20 | 236 | 30 | 24 | 5 | 0 | 292 | 19 | 5 | 7 | 70 | 32 | 15 | 19 | 40 | 63 | 5 | 22 |
| **Alaska** | 0 | 54 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| **Arizona** | 3 | 0 | 1384 | 3 | 122 | 15 | 4 | 1 | 0 | 5 | 0 | 1 | 2 | 10 | 1 | 0 | 1 | 3 | 4 | 1 | 1 |
| **Arkansas** | 13 | 2 | 16 | 1375 | 107 | 23 | 14 | 3 | 0 | 106 | 7 | 0 | 4 | 37 | 38 | 9 | 11 | 22 | 65 | 3 | 13 |
| **California** | 32 | 7 | 381 | 28 | 12944 | 223 | 51 | 1 | 7 | 247 | 6 | 115 | 60 | 118 | 54 | 20 | 23 | 16 | 35 | 12 | 21 |
| **Colorado** | 8 | 0 | 11 | 4 | 89 | 1216 | 9 | 2 | 1 | 13 | 1 | 2 | 3 | 15 | 2 | 6 | 7 | 9 | 11 | 2 | 4 |
| **Connecticut** | 2 | 1 | 9 | 1 | 116 | 10 | 1593 | 2 | 1 | 45 | 2 | 2 | 0 | 10 | 7 | 5 | 6 | 3 | 5 | 3 | 2 |
| **Delaware** | 5 | 0 | 6 | 5 | 62 | 8 | 6 | 317 | 1 | 42 | 2 | 0 | 2 | 3 | 9 | 4 | 5 | 6 | 7 | 1 | 57 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| **Florida** | 70 | 4 | 19 | 10 | 131 | 26 | 12 | 8 | 4 | 3286 | 15 | 6 | 9 | 46 | 28 | 9 | 13 | 22 | 34 | 8 | 19 |
| **Georgia** | 225 | 12 | 45 | 47 | 276 | 21 | 27 | 5 | 8 | 830 | 4860 | 17 | 19 | 83 | 22 | 15 | 6 | 23 | 102 | 14 | 34 |
| **Hawaii** | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 5 | 0 | 103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **Idaho** | 1 | 0 | 1 | 1 | 14 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 248 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 1 |
| **Illinois** | 41 | 19 | 46 | 26 | 479 | 44 | 113 | 24 | 17 | 139 | 26 | 26 | 37 | 6904 | 221 | 151 | 77 | 107 | 52 | 28 | 261 |
| **Indiana** | 45 | 11 | 31 | 43 | 230 | 56 | 31 | 9 | 8 | 256 | 16 | 0 | 18 | 461 | 4053 | 100 | 65 | 182 | 38 | 24 | 37 |
| **Iowa** | 12 | 2 | 5 | 9 | 64 | 10 | 15 | 3 | 0 | 21 | 4 | 0 | 3 | 84 | 38 | 1715 | 26 | 38 | 32 | 3 | 3 |
| **Kansas** | 7 | 0 | 7 | 11 | 93 | 57 | 0 | 0 | 1 | 18 | 2 | 0 | 2 | 29 | 28 | 15 | 1301 | 5 | 10 | 2 | 8 |
| **Kentucky** | 57 | 5 | 8 | 40 | 120 | 15 | 22 | 7 | 4 | 156 | 17 | 7 | 8 | 98 | 129 | 19 | 35 | 2154 | 61 | 7 | 28 |
| **Louisiana** | 90 | 3 | 8 | 78 | 135 | 10 | 24 | 5 | 0 | 60 | 4 | 0 | 7 | 78 | 39 | 53 | 8 | 60 | 823 | 5 | 3 |
| **Maine** | 2 | 0 | 2 | 2 | 17 | 2 | 5 | 0 | 0 | 7 | 0 | 0 | 1 | 8 | 4 | 1 | 1 | 2 | 2 | 403 | 2 |
| **Maryland** | 4 | 0 | 6 | 5 | 44 | 7 | 2 | 6 | 96 | 14 | 0 | 0 | 1 | 10 | 11 | 3 | 0 | 1 | 6 | 1 | 1550 |
| **Massachusetts** | 4 | 5 | 36 | 5 | 141 | 14 | 108 | 7 | 4 | 48 | 4 | 7 | 9 | 56 | 29 | 2 | 8 | 12 | 7 | 93 | 41 |
| **Michigan** | 36 | 0 | 99 | 66 | 560 | 95 | 11 | 18 | 10 | 295 | 21 | 17 | 21 | 234 | 342 | 28 | 33 | 67 | 93 | 17 | 68 |
| **Minnesota** | 4 | 0 | 24 | 3 | 199 | 79 | 11 | 5 | 3 | 49 | 2 | 5 | 7 | 100 | 51 | 70 | 13 | 22 | 28 | 5 | 12 |
| **Mississippi** | 29 | 3 | 20 | 9 | 89 | 8 | 17 | 4 | 0 | 64 | 8 | 4 | 0 | 50 | 25 | 6 | 13 | 11 | 73 | 4 | 2 |
| **Missouri** | 16 | 3 | 3 | 30 | 66 | 23 | 3 | 4 | 2 | 61 | 5 | 4 | 5 | 119 | 25 | 40 | 77 | 17 | 21 | 4 | 15 |
| **Montana** | 1 | 0 | 1 | 1 | 5 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| **Nebraska** | 3 | 1 | 4 | 6 | 31 | 9 | 7 | 2 | 1 | 26 | 1 | 0 | 9 | 27 | 14 | 46 | 8 | 16 | 9 | 2 | 7 |
| **Nevada** | 1 | 0 | 6 | 1 | 94 | 4 | 1 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 |
| **New Hampshire** | 10 | 0 | 14 | 10 | 105 | 0 | 12 | 3 | 0 | 53 | 2 | 3 | 0 | 35 | 24 | 8 | 10 | 12 | 15 | 3 | 12 |
| **New Jersey** | 15 | 5 | 40 | 8 | 209 | 35 | 67 | 7 | 5 | 93 | 3 | 7 | 11 | 51 | 26 | 4 | 21 | 17 | 19 | 6 | 104 |
| **New Mexico** | 0 | 0 | 2 | 2 | 28 | 24 | 2 | 0 | 0 | 6 | 0 | 0 | 1 | 6 | 4 | 1 | 2 | 0 | 2 | 0 | 2 |
| **New York** | 16 | 4 | 33 | 7 | 322 | 11 | 104 | 4 | 4 | 81 | 3 | 4 | 8 | 59 | 39 | 4 | 2 | 7 | 12 | 7 | 46 |
| **North Carolina** | 58 | 0 | 35 | 14 | 293 | 17 | 33 | 13 | 7 | 228 | 31 | 12 | 17 | 54 | 24 | 10 | 14 | 50 | 36 | 7 | 81 |
| **North Dakota** | 0 | 0 | 1 | 1 | 5 | 3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| **Ohio** | 207 | 20 | 151 | 76 | 664 | 124 | 83 | 13 | 17 | 491 | 44 | 27 | 22 | 423 | 405 | 146 | 113 | 289 | 83 | 27 | 156 |
| **Oklahoma** | 8 | 3 | 26 | 19 | 250 | 50 | 5 | 4 | 2 | 96 | 9 | 4 | 5 | 67 | 33 | 11 | 37 | 5 | 14 | 4 | 19 |
| **Oregon** | 0 | 0 | 3 | 3 | 88 | 8 | 3 | 1 | 0 | 1 | 0 | 0 | 13 | 2 | 6 | 2 | 2 | 3 | 3 | 1 | 3 |
| **Pennsylvania** | 61 | 41 | 35 | 16 | 552 | 48 | 99 | 36 | 47 | 342 | 12 | 58 | 23 | 135 | 217 | 59 | 55 | 31 | 91 | 12 | 237 |
| **Rhode Island** | 8 | 2 | 11 | 4 | 83 | 1 | 22 | 2 | 0 | 6 | 2 | 0 | 3 | 9 | 17 | 6 | 7 | 0 | 12 | 2 | 4 |
| **South Carolina** | 131 | 9 | 46 | 15 | 188 | 67 | 41 | 35 | 0 | 220 | 42 | 12 | 15 | 132 | 31 | 5 | 43 | 70 | 63 | 58 | 50 |
| **South Dakota** | 1 | 0 | 2 | 1 | 9 | 2 | 1 | 0 | 0 | 7 | 0 | 0 | 0 | 2 | 3 | 2 | 1 | 1 | 1 | 0 | 1 |
| **Tennessee** | 96 | 11 | 20 | 52 | 174 | 136 | 57 | 12 | 0 | 113 | 40 | 0 | 20 | 95 | 35 | 39 | 14 | 61 | 87 | 19 | 19 |
| **Texas** | 116 | 11 | 102 | 122 | 1138 | 287 | 24 | 21 | 0 | 265 | 35 | 15 | 19 | 338 | 161 | 76 | 102 | 63 | 240 | 20 | 43 |
| **Utah** | 2 | 0 | 8 | 2 | 69 | 3 | 3 | 0 | 0 | 3 | 0 | 0 | 40 | 3 | 5 | 1 | 1 | 2 | 3 | 1 | 2 |
| **Vermont** | 1 | 0 | 1 | 1 | 2 | 1 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 0 | 1 |
| **Virginia** | 32 | 6 | 7 | 7 | 162 | 45 | 16 | 8 | 5 | 83 | 12 | 9 | 11 | 54 | 31 | 25 | 27 | 46 | 47 | 9 | 105 |
| **Washington** | 4 | 42 | 8 | 4 | 110 | 3 | 5 | 0 | 0 | 12 | 0 | 5 | 32 | 6 | 10 | 3 | 3 | 5 | 5 | 1 | 4 |
| **West Virginia** | 15 | 0 | 20 | 14 | 151 | 23 | 17 | 4 | 0 | 6 | 1 | 0 | 5 | 50 | 34 | 12 | 14 | 10 | 22 | 4 | 17 |
| **Wisconsin** | 19 | 14 | 47 | 39 | 530 | 66 | 72 | 16 | 11 | 187 | 7 | 20 | 9 | 379 | 115 | 69 | 30 | 38 | 49 | 18 | 49 |
| **Wyoming** | 1 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| *IFIj* | 415 | 59 | 377 | 265 | 2589 | 407 | 318 | 93 | 57 | 1222 | 6109 | 87 | 116 | 1217 | 786 | 377 | 303 | 476 | 371 | 112 | 429 |
| *Σ Vij* | 3012 | 306 | 2818 | 2242 | 21633 | 2962 | 2775 | 614 | 303 | 8391 | 5266 | 499 | 742 | 10554 | 6433 | 2820 | 2259 | 3552 | 2388 | 847 | 3178 |
| *INTDj* | 2963 | 299 | 2776 | 2215 | 21373 | 2910 | 2740 | 605 | 295 | 8238 | 5214 | 486 | 728 | 10436 | 6347 | 2787 | 2230 | 3505 | 2343 | 834 | 3130 |
| Sale_V | 4759 | 507 | 4438 | 3482 | 33642 | 4678 | 4296 | 982 | 499 | 13351 | 15799 | 814 | 1192 | 16349 | 10027 | 4440 | 3559 | 5594 | 3832 | 1332 | 5009 |

*(Continued)*

| | MA | MI | MN | MS | MO | MT | NE | NV | NH | NJ | NM | NY | NC | ND | OH | OK | OR | PA | RI | SC | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alabama | 12 | 17 | 26 | 23 | 36 | 6 | 13 | 7 | 9 | 32 | 7 | 84 | 38 | 5 | 198 | 18 | 15 | 81 | 5 | 30 | 4 |
| **Alaska** | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **Arizona** | 1 | 9 | 4 | 2 | 3 | 1 | 2 | 8 | 1 | 4 | 16 | 3 | 1 | 1 | 2 | 2 | 7 | 5 | 0 | 5 | 1 |
| **Arkansas** | 5 | 31 | 8 | 15 | 22 | 3 | 7 | 4 | 5 | 15 | 4 | 17 | 37 | 3 | 33 | 98 | 9 | 24 | 3 | 49 | 2 |
| **California** | 40 | 58 | 52 | 21 | 40 | 23 | 29 | 131 | 21 | 79 | 31 | 172 | 98 | 11 | 97 | 36 | 202 | 67 | 13 | 10 | 6 |
| **Colorado** | 8 | 3 | 18 | 0 | 7 | 2 | 5 | 3 | 3 | 9 | 19 | 9 | 3 | 2 | 21 | 5 | 2 | 16 | 2 | 13 | 2 |
| **Connecticut** | 62 | 7 | 9 | 4 | 2 | 2 | 3 | 2 | 21 | 45 | 2 | 110 | 24 | 2 | 17 | 6 | 5 | 17 | 2 | 1 | 1 |
| **Delaware** | 32 | 16 | 7 | 5 | 5 | 2 | 0 | 2 | 2 | 55 | 2 | 59 | 12 | 0 | 24 | 5 | 6 | 22 | 11 | 8 | 0 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Florida** | 26 | 50 | 16 | 11 | 18 | 9 | 14 | 2 | 2 | 45 | 1 | 91 | 41 | 7 | 55 | 24 | 22 | 54 | 1 | 34 | 6 |
| **Georgia** | 30 | 89 | 72 | 54 | 37 | 15 | 7 | 6 | 20 | 26 | 21 | 49 | 180 | 12 | 136 | 23 | 7 | 75 | 12 | 194 | 11 |
| **Hawaii** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 14 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| **Idaho** | 2 | 2 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 5 | 1 | 0 | 2 | 1 | 5 | 1 | 0 | 1 | 0 |
| **Illinois** | 74 | 469 | 200 | 25 | 166 | 13 | 113 | 36 | 4 | 144 | 9 | 183 | 96 | 26 | 326 | 79 | 26 | 194 | 24 | 24 | 28 |
| **Indiana** | 51 | 493 | 86 | 15 | 185 | 16 | 101 | 25 | 3 | 58 | 22 | 180 | 89 | 12 | 487 | 43 | 8 | 151 | 14 | 87 | 10 |
| **Iowa** | 8 | 75 | 84 | 9 | 81 | 15 | 73 | 4 | 5 | 10 | 4 | 32 | 29 | 39 | 51 | 15 | 16 | 26 | 3 | 10 | 38 |
| **Kansas** | 2 | 19 | 13 | 5 | 49 | 2 | 32 | 3 | 3 | 14 | 2 | 46 | 7 | 2 | 15 | 24 | 4 | 18 | 2 | 13 | 1 |
| **Kentucky** | 63 | 182 | 25 | 34 | 34 | 7 | 2 | 7 | 1 | 70 | 10 | 60 | 60 | 6 | 210 | 15 | 5 | 74 | 0 | 40 | 5 |
| **Louisiana** | 24 | 60 | 25 | 69 | 13 | 6 | 13 | 7 | 8 | 30 | 5 | 81 | 62 | 17 | 58 | 112 | 7 | 54 | 5 | 28 | 4 |
| **Maine** | 16 | 4 | 2 | 1 | 2 | 0 | 0 | 1 | 4 | 3 | 0 | 10 | 3 | 0 | 2 | 1 | 0 | 2 | 0 | 3 | 0 |
| **Maryland** | 21 | 9 | 6 | 3 | 2 | 1 | 3 | 0 | 2 | 20 | 1 | 59 | 8 | 1 | 9 | 4 | 3 | 46 | 1 | 3 | 0 |
| **Massachusetts** | 3216 | 38 | 25 | 8 | 14 | 8 | 17 | 9 | 11 | 92 | 9 | 299 | 57 | 6 | 75 | 5 | 6 | 59 | 43 | 42 | 5 |
| **Michigan** | 95 | 5663 | 93 | 12 | 178 | 19 | 26 | 23 | 17 | 57 | 24 | 86 | 90 | 4 | 557 | 35 | 48 | 126 | 1 | 31 | 12 |
| **Minnesota** | 48 | 44 | 2643 | 14 | 52 | 7 | 69 | 3 | 8 | 27 | 6 | 37 | 35 | 36 | 14 | 18 | 16 | 27 | 5 | 3 | 49 |
| **Mississippi** | 13 | 13 | 21 | 1133 | 14 | 4 | 37 | 5 | 6 | 13 | 5 | 19 | 23 | 4 | 66 | 14 | 12 | 22 | 4 | 7 | 0 |
| **Missouri** | 9 | 66 | 32 | 11 | 2772 | 5 | 26 | 1 | 3 | 7 | 5 | 100 | 12 | 4 | 46 | 62 | 45 | 24 | 4 | 19 | 6 |
| **Montana** | 1 | 2 | 1 | 0 | 0 | 99 | 0 | 0 | 0 | 1 | 0 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| **Nebraska** | 6 | 32 | 18 | 1 | 22 | 2 | 612 | 2 | 2 | 10 | 2 | 16 | 5 | 1 | 19 | 3 | 2 | 19 | 0 | 10 | 13 |
| **Nevada** | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 638 | 0 | 1 | 1 | 5 | 1 | 0 | 1 | 1 | 4 | 1 | 0 | 0 | 0 |
| **New Hampshire** | 25 | 32 | 14 | 7 | 11 | 3 | 1 | 4 | 644 | 13 | 0 | 106 | 19 | 0 | 29 | 10 | 8 | 11 | 8 | 17 | 2 |
| **New Jersey** | 122 | 30 | 40 | 8 | 24 | 9 | 19 | 11 | 12 | 4200 | 8 | 492 | 77 | 7 | 81 | 6 | 24 | 151 | 7 | 47 | 6 |
| **New Mexico** | 4 | 5 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 256 | 11 | 3 | 0 | 4 | 0 | 1 | 3 | 0 | 0 | 0 |
| **New York** | 64 | 87 | 35 | 4 | 40 | 3 | 16 | 9 | 19 | 193 | 8 | 5714 | 45 | 6 | 122 | 2 | 19 | 262 | 4 | 39 | 5 |
| **North Carolina** | 112 | 86 | 42 | 15 | 59 | 1 | 14 | 17 | 19 | 50 | 16 | 289 | 4111 | 11 | 154 | 41 | 42 | 109 | 11 | 410 | 9 |
| **North Dakota** | 1 | 1 | 11 | 0 | 0 | 10 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 163 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| **Ohio** | 196 | 815 | 168 | 59 | 169 | 12 | 64 | 30 | 16 | 250 | 36 | 678 | 347 | 11 | 6868 | 86 | 125 | 527 | 27 | 136 | 24 |
| **Oklahoma** | 6 | 77 | 20 | 10 | 49 | 4 | 10 | 5 | 6 | 16 | 5 | 56 | 9 | 3 | 74 | 994 | 25 | 39 | 4 | 24 | 3 |
| **Oregon** | 6 | 1 | 2 | 2 | 2 | 8 | 2 | 2 | 1 | 4 | 0 | 1 | 1 | 1 | 5 | 2 | 1122 | 2 | 1 | 4 | 0 |
| **Pennsylvania** | 161 | 181 | 66 | 30 | 52 | 47 | 24 | 61 | 28 | 346 | 7 | 557 | 141 | 9 | 281 | 34 | 34 | 6760 | 21 | 43 | 5 |
| **Rhode Island** | 18 | 25 | 1 | 5 | 1 | 2 | 5 | 3 | 8 | 23 | 4 | 46 | 15 | 0 | 10 | 7 | 7 | 17 | 424 | 13 | 2 |
| **South Carolina** | 59 | 168 | 59 | 38 | 42 | 13 | 15 | 16 | 54 | 48 | 16 | 251 | 529 | 10 | 224 | 41 | 34 | 103 | 4 | 1715 | 9 |
| **South Dakota** | 0 | 6 | 2 | 0 | 2 | 1 | 5 | 0 | 1 | 2 | 0 | 6 | 2 | 0 | 3 | 1 | 1 | 2 | 0 | 2 | 240 |
| **Tennessee** | 116 | 203 | 37 | 60 | 43 | 15 | 14 | 7 | 5 | 41 | 18 | 153 | 66 | 12 | 149 | 21 | 44 | 70 | 15 | 74 | 11 |
| **Texas** | 79 | 256 | 75 | 82 | 114 | 48 | 67 | 67 | 19 | 137 | 157 | 188 | 185 | 17 | 284 | 260 | 77 | 210 | 14 | 133 | 14 |
| **Utah** | 6 | 2 | 2 | 2 | 2 | 4 | 1 | 6 | 1 | 3 | 2 | 3 | 1 | 0 | 3 | 1 | 8 | 1 | 0 | 3 | 0 |
| **Vermont** | 14 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 2 | 0 | 15 | 1 | 0 | 4 | 1 | 1 | 5 | 0 | 1 | 0 |
| **Virginia** | 54 | 80 | 13 | 3 | 21 | 9 | 3 | 11 | 31 | 100 | 11 | 168 | 93 | 7 | 158 | 8 | 25 | 128 | 8 | 62 | 4 |
| **Washington** | 2 | 1 | 5 | 1 | 3 | 1 | 2 | 3 | 2 | 2 | 1 | 4 | 2 | 1 | 6 | 3 | 73 | 4 | 1 | 6 | 1 |
| **West Virginia** | 36 | 65 | 21 | 10 | 15 | 4 | 0 | 0 | 6 | 26 | 5 | 93 | 17 | 0 | 105 | 0 | 12 | 81 | 0 | 24 | 0 |
| **Wisconsin** | 32 | 255 | 289 | 43 | 51 | 19 | 40 | 7 | 26 | 49 | 25 | 384 | 50 | 19 | 204 | 59 | 9 | 96 | 15 | 27 | 13 |
| **Wyoming** | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 0 |
| *IFIj* | 539 | 1373 | 509 | 218 | 535 | 85 | 238 | 157 | 125 | 683 | 135 | 1420 | 799 | 80 | 1488 | 343 | 281 | 1011 | 81 | 539 | 83 |
| *Σ Vij* | 4983 | 9835 | 4391 | 1858 | 4458 | 486 | 1511 | 1187 | 1061 | 6381 | 788 | 11060 | 6745 | 476 | 11294 | 2229 | 2176 | 9789 | 719 | 3448 | 554 |
| *INTDj* | 4926 | 9711 | 4339 | 1834 | 4407 | 475 | 1484 | 1171 | 1046 | 6316 | 772 | 10899 | 6658 | 466 | 11141 | 2191 | 2145 | 9679 | 709 | 3375 | 545 |
| Sales_V | 7670 | 15567 | 6806 | 2883 | 6934 | 793 | 2429 | 1867 | 1647 | 9812 | 1281 | 17333 | 10478 | 772 | 17753 | 3573 | 3412 | 15000 | 1111 | 5537 | 884 |

*(Continued)*

| | TN | TX | UT | VM | VA | WA | WV | WI | WY | *IFEi* | ? *Vij* | *INTOi* | **Sale_V** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Alabama** | 93 | 221 | 17 | 3 | 15 | 4 | 6 | 12 | 3 | 598 | 3472 | 3525 | 5654 |
| **Alaska** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 85 | 85 | 120 |
| **Arizona** | 1 | 14 | 3 | 0 | 9 | 6 | 1 | 3 | 0 | 142 | 1676 | 1685 | 2525 |
| **Arkansas** | 25 | 170 | 10 | 0 | 1 | 11 | 3 | 9 | 2 | 341 | 2494 | 2526 | 3938 |
| **California** | 33 | 301 | 122 | 3 | 28 | 382 | 1 | 58 | 12 | 1778 | 16574 | 16682 | 25490 |
| **Colorado** | 14 | 48 | 30 | 1 | 22 | 27 | 0 | 12 | 18 | 167 | 1741 | 1757 | 2650 |
| **Connecticut** | 11 | 19 | 5 | 11 | 18 | 10 | 2 | 9 | 1 | 280 | 2252 | 2272 | 3517 |
| **Delaware** | 4 | 21 | 0 | 1 | 14 | 4 | 2 | 21 | 0 | 157 | 890 | 905 | 1453 |
| **D.C** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 64 | 64 | 91 |
| **Florida** | 25 | 126 | 26 | 4 | 20 | 21 | 2 | 15 | 0 | 457 | 4544 | 4582 | 6946 |
| **Georgia** | 137 | 198 | 21 | 0 | 52 | 18 | 16 | 83 | 8 | 2283 | 8302 | 8365 | 14701 |
| **Hawaii** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 154 | 154 | 223 |
| **Idaho** | 1 | 2 | 14 | 0 | 2 | 11 | 0 | 1 | 1 | 23 | 335 | 337 | 497 |
| **Illinois** | 82 | 563 | 46 | 16 | 50 | 85 | 31 | 334 | 15 | 1573 | 12318 | 12473 | 19293 |
| **Indiana** | 111 | 263 | 46 | 8 | 156 | 56 | 9 | 198 | 9 | 1073 | 8708 | 8829 | 13585 |
| **a** | 19 | 77 | 3 | 2 | 22 | 32 | 1 | 70 | 2 | 411 | 2941 | 2977 | 4655 |
| **Kansas** | 6 | 78 | 9 | 1 | 3 | 11 | 1 | 13 | 1 | 255 | 1997 | 2018 | 3128 |
| **Kentucky** | 189 | 243 | 21 | 4 | 48 | 13 | 5 | 33 | 0 | 836 | 4465 | 4527 | 7362 |
| **Louisiana** | 68 | 341 | 17 | 3 | 69 | 29 | 6 | 41 | 3 | 867 | 2755 | 2806 | 5031 |
| **Maine** | 3 | 8 | 1 | 0 | 4 | 2 | 0 | 5 | 0 | 45 | 539 | 543 | 812 |
| **Maryland** | 8 | 10 | 4 | 1 | 43 | 1 | 1 | 6 | 1 | 162 | 2045 | 2059 | 3064 |
| **Massachusetts** | 37 | 114 | 4 | 41 | 33 | 20 | 8 | 32 | 4 | 651 | 4977 | 5028 | 7816 |
| **Michigan** | 127 | 309 | 11 | 10 | 63 | 91 | 3 | 120 | 10 | 1252 | 10072 | 10205 | 15728 |
| **Minnesota** | 14 | 68 | 17 | 3 | 10 | 25 | 6 | 108 | 3 | 457 | 4108 | 4152 | 6340 |
| **Mississippi** | 43 | 79 | 1 | 2 | 14 | 11 | 5 | 24 | 2 | 261 | 2055 | 2081 | 3217 |
| **Missouri** | 41 | 144 | 7 | 2 | 44 | 25 | 4 | 25 | 0 | 551 | 4092 | 4133 | 6449 |
| **Montana** | 1 | 3 | 0 | 0 | 2 | 1 | 0 | 1 | 13 | 7 | 148 | 150 | 216 |
| **Nebraska** | 10 | 17 | 5 | 0 | 16 | 9 | 2 | 25 | 1 | 112 | 1111 | 1126 | 1699 |
| **Nevada** | 1 | 3 | 4 | 0 | 2 | 6 | 0 | 1 | 0 | 77 | 797 | 801 | 1213 |
| **New Hampshire** | 3 | 57 | 9 | 78 | 28 | 16 | 3 | 8 | 0 | 150 | 1498 | 1521 | 2290 |
| **New Jersey** | 23 | 139 | 10 | 5 | 48 | 24 | 2 | 22 | 5 | 792 | 6410 | 6476 | 10002 |
| **New Mexico** | 3 | 31 | 2 | 0 | 0 | 2 | 0 | 2 | 0 | 14 | 419 | 423 | 601 |
| **New York** | 19 | 196 | 11 | 13 | 46 | 37 | 4 | 46 | 4 | 1087 | 7845 | 7912 | 12406 |
| **North Carolina** | 158 | 131 | 19 | 6 | 212 | 73 | 26 | 36 | 7 | 981 | 7321 | 7407 | 11530 |
| **North Dakota** | 1 | 2 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 16 | 219 | 221 | 327 |
| **Ohio** | 241 | 593 | 41 | 16 | 182 | 114 | 237 | 234 | 16 | 2328 | 15897 | 16133 | 25313 |
| **Oklahoma** | 19 | 191 | 7 | 2 | 9 | 33 | 4 | 94 | 2 | 350 | 2477 | 2518 | 3926 |
| **Oregon** | 1 | 7 | 2 | 0 | 7 | 132 | 1 | 3 | 0 | 161 | 1460 | 1470 | 2250 |
| **Pennsylvania** | 80 | 214 | 21 | 8 | 123 | 39 | 40 | 80 | 24 | 1652 | 11726 | 11859 | 18580 |
| **Rhode Island** | 13 | 13 | 6 | 1 | 19 | 13 | 0 | 13 | 0 | 126 | 917 | 930 | 1449 |
| **South Carolina** | 83 | 255 | 39 | 20 | 115 | 64 | 13 | 84 | 7 | 949 | 5400 | 5482 | 8819 |
| **South Dakota** | 2 | 7 | 1 | 0 | 3 | 2 | 0 | 2 | 3 | 33 | 336 | 339 | 512 |
| **Tennessee** | 3166 | 209 | 17 | 1 | 123 | 65 | 4 | 47 | 8 | 984 | 5912 | 5989 | 9578 |
| **Texas** | 152 | 8560 | 65 | 11 | 147 | 136 | 22 | 79 | 12 | 2369 | 14869 | 15056 | 23941 |
| **Utah** | 0 | 13 | 662 | 0 | 2 | 12 | 1 | 2 | 2 | 81 | 895 | 901 | 1355 |
| **Vermont** | 1 | 2 | 1 | 190 | 2 | 1 | 0 | 1 | 0 | 25 | 262 | 264 | 398 |
| **Virginia** | 52 | 129 | 26 | 5 | 2840 | 20 | 17 | 46 | 5 | 733 | 4885 | 4945 | 7803 |
| **Washington** | 7 | 7 | 14 | 1 | 1 | 1926 | 1 | 5 | 1 | 198 | 2350 | 2362 | 3538 |
| **West Virginia** | 9 | 84 | 13 | 0 | 37 | 90 | 548 | 11 | 0 | 472 | 1735 | 1768 | 3066 |
| **Wisconsin** | 86 | 176 | 30 | 10 | 85 | 85 | 20 | 3581 | 10 | 901 | 7578 | 7686 | 11776 |
| **Wyoming** | 1 | 4 | 1 | 0 | 2 | 0 | 0 | 1 | 81 | 12 | 120 | 121 | 183 |
| *IFIj* | 666 | 1752 | 186 | 63 | 599 | 489 | 144 | 644 | 51 | | | | |
| ? *Vij* | 5224 | 14458 | 1441 | 484 | 4797 | 3799 | 1057 | 5658 | 298 | | 206239 | 208628 | 327053 |
| *INTDj* | 5158 | 14281 | 1418 | 475 | 4737 | 3744 | 1040 | 5587 | 292 | | 203473 | | |
| Sales_V | 8180 | 22514 | 2259 | 760 | 7495 | 5956 | 1669 | 8753 | 484 | | 330193 | | |

**< NOTE >**

-V=Value (Mil $)

Notation

-*IFEi*=IMPLAN Foreign Export of State *i*

-*INTOi*=*ITOi*-*IFEi*, meaning IMPLAN Net Total Origin without Foreign Export.

-*IFIj*=IMPLAN Adjusted Foreign Import of State *j* (=*RIFIj* + *OIFIj*)

## IV. Results

The estimated 2001 trade flows between U.S. states sectors for 29 USC Commodities are estimated according to AFM and DFM. In <Table-2> and <Table-3>, we suggest estimated trade flow matrices for USC Sector 15 as an example, respectively, to show AFM's and DFM's. All values in <Table-2> are rounded off to the nearest integer and 0 values are given by Symbol 1 in <Appendix-B> or estimated 0s. Only unreported values are estimated represented as Symbol 2 or 3 without changing all given values, in <Appendix-B>. Total estimated value for USC Sector 15 is 278,797 million dollars, showing the 35 million dollars difference from 1997 CFS's, corresponding to 99.99 percent. For the results of each state, the ratios, $\sum_i V_{ij} / \boldsymbol{TO_i}$ (or $\sum_j V_{ij} / \boldsymbol{TD_j}$), are almost close to 1.[1] Although AFM does not consider the effect of distance, it is hard to say that the results violate distance effect severely for its estimator when comparing the estimated matrix in <Table-2> and raw table in <Appendix-B>.

Based on <Table-2>, DFM was used to estimate 2001 trade flows between states. These are shown in <Table-3>. For the sake of accuracy of the estimated values, we suggest the sum of trade flow between states ($\sum_i V_{ij}$ or $\sum_j V_{ij}$) and IMPLAN total value ($INTO_i$ or $INTD_j$) and by comparing the ratios of the two, which are close to 1 for every state. Foreign Exports and Foreign Imports are suggested as the trade flows to/from the Rest of World, although Foreign Imports are already included in domestic trade flows between states.[2] Since the values in <Table-3> are producer values, by dividing 0.72 meaning producer/purchaser ratio for USC 15, sale values enable comparisons with <Table-2>. For instance, since the estimated producer value of CA to CA in 2001 is 12,944 million dollars, about 43 percent (=100*(12,944/0.72 - 12,557)/19,953) is increasing from 1997 total origin value (=12,557million dollars) as nominal value. Similarly, all other values in <Table-3> can be compared with those in <Table-2>. However, since our current estimated values of trade flows in the states with ports does not include Foreign Exports, the values might be overestimated if *IFE* is added to Diagonal value in trade flows and compared with CFS which counts Foreign Exports as the Domestic Flows. Also, Sale_V, meaning $\{(\sum_i V_{ij} + IFE_i)/0.72\}$ or $\{(\sum_j V_{ij} + IFI_j)/0.72\}$ is suggested in <Table-3> to compare total values of <Table-2>. For instance, the sum of origin flows from CA is increased by 30 percent (=100*(25,490-19,953)/19,953) in 2001 as nominal value.

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[1] <Appendix-B> shows all reported total value for destination and almost reported total value for origin except D.C. and Wyoming. Since these unreported total values are adjusted first by equation (1) such as D.C. and Wyoming, its estimators by AFM show bigger different ratios than other reported values. Also, smaller total values lead to bigger different ratios from 1 between $\sum_i V_{ij}$ (or $\sum_j V_{ij}$) and $\boldsymbol{TO_i}$ (or $\boldsymbol{TD_j}$).

[2] Therefore, if consider the value for Rest of World, Foreign Imports will be doubled.

# VI. Conclusions

Although a large variety of IO models have been developed, the construction of multiregional IO models has remained a challenging task. In this study, we suggest how trade flows between U.S. states can be estimated and updated using secondary data, as a basis on which to build a NIEMO-type multiregional IO model.

We applied a two-step method programmed by Excel Visual Basic, based on incomplete 1997 CFS trade flow data between states, and IMPLAN regional commodity balance data. Before estimating, we created several kinds of conversion tables to reconcile different data code systems. With the Adjusted Flow Model, incomplete trade flows in 1997 CFS are filled out. Based on this trade flows matrix, including Foreign Imports/Exports in U.S. trade flows, we estimated the 2001 trade flows matrix only including Foreign Imports using a Double constrained Fratar Model. Those 2001 trade flows are constructed for 29 USC Commodity Sectors in the final step. As an example, USC Sector 15 is shown in the results section, where we can verify that our model and estimations are reasonably acceptable. However, our 2001 model based on 1997 data still has some limitations. As soon as 2002 CFS data are published more accurate results can be obtained.

On the basis of these trade flows, by constructing traditional industry IO models for 51 U.S. states, we will create NIEMO as the next step. We will also combine NIEMO with an intrametropolitan model of Southern California to explore the impacts of major local exogenous shocks on interregional trade.

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<Appendix-A> 2001 USC Two-Digit Sector description and conversion table

| Classification | USC | Description | SCTG | NAICS |
|---|---|---|---|---|
| Commodity Sectors | USC01 | Live animals and live fish & Meat, fish, seafood, and their preparations | (1+5) | 11,31 |
| | USC02 | Cereal grains & Other agricultural products except for Animal Feed | (2+3) | 11,31 |
| | USC03 | Animal feed and products of animal origin, n.e.c. | 4 | 11,31 |
| | USC04 | Milled grain products and preparations, and bakery products | 6 | 31 |
| | USC05 | Other prepared foodstuffs and fats and oils | 7 | 11,31 |
| | USC06 | Alcoholic beverages | 8 | 31,32 |
| | USC07 | Tobacco products | 9 | 11,31 |
| | USC08 | Nonmetallic minerals (Monumental or building stone, Natural sands, Gravel and crushed stone, n.e.c.) | (10~13) | 21,32 |
| | USC09 | Metallic ores and concentrates | 14 | 21,32 |
| | USC10 | Coal and petroleum products (Coal and Fuel oils, n.e.c.) | (15~19) | 21,32 |
| | USC11 | Basic chemicals | 20 | 32 |
| | USC12 | Pharmaceutical products | 21 | 32,33 |
| | USC13 | Fertilizers | 22 | 32 |
| | USC14 | Chemical products and preparations, n.e.c. | 23 | 31,32 |
| | USC15 | Plastics and rubber | 24 | 31,32,33 |
| | USC16 | Logs and other wood in the rough & Wood products | (25+26) | 11,32 |
| | USC17 | Pulp, newsprint, paper, and paperboard & Paper or paperboard articles | (27+28) | 32 |
| | USC18 | Printed products | 29 | 32,51 |
| | USC19 | Textiles, leather, and articles of textiles or leather | 30 | 11,31,32,33 |
| | USC20 | Nonmetallic mineral products | 31 | 32,33 |
| | USC21 | Base metal in primary or semi-finished forms and in finished basic shapes | 32 | 33 |
| | USC22 | Articles of base metal | 33 | 33 |
| | USC23 | Machinery | 34 | 32,33 |
| | USC24 | Electronic and other electrical equipment and components, and office equipment | 35 | 32,33,51 |
| | USC25 | Motorized and other vehicles (including parts) | 36 | 32,33 |
| | USC26 | Transportation equipment, n.e.c. | 37 | 33 |
| | USC27 | Precision instruments and apparatus | 38 | 33 |
| | USC28 | Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs | 39 | 33 |
| | USC29 | Miscellaneous manufactured products, Scrap, Mixed freight, and Commodity unknown | (40~99) | 11,31,32,33 |
| Non-Commodity Sectors | USC30 | Utility | | 22 |
| | USC31 | Construction | | 23 |
| | USC32 | Wholesale Trade | | 42 |
| | USC33 | Transportation | | 48 |
| | USC34 | Postal and Warehousing | | 49 |
| | USC35 | Retail Trade | | (44+45) |
| | USC36 | Broadcasting and information services* | | (515~519) |
| | USC37 | Finance and Insurance | | 52 |
| | USC38 | Real estate and rental and leasing | | 53 |
| | USC39 | Professional, Scientific, and Technical services | | 54 |
| | USC40 | Management of companies and enterprises | | 55 |
| | USC41 | Administrative support and waste management | | 56 |
| | USC42 | Education Services | | 61 |
| | USC43 | Health Care and Social Assistances | | 62 |
| | USC44 | Arts, Entertainment, and Recreation | | 71 |
| | USC45 | Accommodation and Food services | | 72 |
| | USC46 | Public administration | | 92 |
| | USC47 | Other services except public administration** | | 81 |

*Publishing, Motion pictures, and Recording (IMPLAN 413-415, 417-419, or NAICS 511~512) are excluded in this sector and included in Commodity Sectors

**USC47 includes NAICS 81plus Support activities (18=Agriculture and forestry, 27-29=Mining) and Etc. (243=Machine shops) in IMPLAN

<Appendix-B> Trade flows matrix between States of USC 15 (=SCTG 24) sector from 1997 CFS

| | AL | | AK | | AZ | | AR | | CA | | CO | | CT | | DE | | DC | | FL | | GA | | HI | | ID | | IL | | IN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S |
| **Alabama** | 824 | - | - | 1 | - | 2 | - | 2 | 220 | - | - | 2 | - | 2 | - | 2 | - | 1 | 201 | - | 305 | - | - | 2 | - | 2 | 154 | - | 75 | - |
| **Alaska** | - | 1 | 77 | - | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Arizona** | - | 2 | - | 2 | 1014 | - | - | 2 | 284 | - | 25 | - | - | 2 | - | 2 | - | 2 | 9 | - | - | 2 | - | 2 | 4 | - | - | 2 | 9 | - |
| **Arkansas** | 27 | - | - | 2 | - | 2 | 785 | - | 140 | - | 21 | - | - | 2 | - | 2 | - | 1 | 108 | - | 162 | - | - | 1 | - | 2 | 115 | - | 128 | - |
| **California** | 76 | - | - | 2 | 610 | - | 104 | - | 12557 | - | 228 | - | 92 | - | 7 | - | - | 2 | 297 | - | 148 | - | 66 | - | 80 | - | 416 | - | 206 | - |
| **Colorado** | - | 2 | - | 1 | 14 | - | 11 | - | 107 | - | 977 | - | - | 2 | - | 2 | - | 2 | 13 | - | 26 | - | - | 2 | - | 2 | 42 | - | 5 | - |
| **Connecticut** | 6 | - | - | 2 | - | 2 | 6 | - | 262 | - | - | 2 | 484 | - | - | 2 | - | 2 | 87 | - | 61 | - | - | 2 | - | 1 | 53 | - | 44 | - |
| **Delaware** | - | 2 | - | 1 | 6 | - | - | 2 | 53 | - | - | 2 | - | 2 | 14 | - | - | 2 | 25 | - | 24 | - | - | 1 | - | 2 | 6 | - | 19 | - |
| **D.C** | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Florida** | 109 | - | - | 2 | 19 | - | 24 | - | 122 | - | 17 | - | 15 | - | - | 2 | - | 2 | 4234 | - | 260 | - | - | 2 | - | 2 | 105 | - | 70 | - |
| **Georgia** | 475 | - | - | 2 | 65 | - | - | 2 | 359 | - | 19 | - | 44 | - | 26 | - | - | 2 | 785 | - | 3085 | - | - | 2 | - | 2 | 259 | - | 73 | - |
| **Hawaii** | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | 186 | - | - | 1 | - | 1 | - | 1 |
| **Idaho** | - | 2 | - | 2 | - | 2 | - | 2 | 44 | - | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | 242 | - | - | 2 | - | 2 |
| **Illinois** | 106 | - | - | 2 | 82 | - | 105 | - | 777 | - | 50 | - | - | 2 | - | 2 | - | 2 | 212 | - | 753 | - | - | 2 | - | 2 | 6895 | - | - | 2 |
| **Indiana** | 49 | - | - | 2 | 23 | - | 73 | - | 157 | - | 27 | - | 26 | - | 26 | - | - | 2 | 118 | - | 189 | - | - | 1 | - | 2 | 750 | - | 2129 | - |
| **Iowa** | - | 2 | - | 2 | 9 | - | 34 | - | 101 | - | 11 | - | - | 2 | - | 2 | - | 1 | 29 | - | 108 | - | - | 1 | 4 | - | 319 | - | 153 | - |
| **Kansas** | - | 2 | - | 1 | 18 | - | 59 | - | 207 | - | 89 | - | 1 | - | 2 | - | - | 2 | 36 | - | 59 | - | - | 1 | - | 2 | 154 | - | 158 | - |
| **Kentucky** | 77 | - | - | 2 | 7 | - | 85 | - | 102 | - | 9 | - | 23 | - | - | 2 | - | 2 | 93 | - | 249 | - | - | 2 | - | 2 | 197 | - | 274 | - |
| **Louisiana** | 254 | - | - | 2 | 15 | - | 350 | - | 241 | - | 12 | - | - | 2 | - | 2 | - | 1 | 114 | - | 134 | - | - | 1 | - | 2 | 333 | - | 173 | - |
| **Maine** | - | 2 | - | 1 | - | 2 | - | 2 | 27 | - | - | 2 | 9 | - | - | 1 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | 29 | - | - | 2 |
| **Maryland** | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | 4 | - | 49 | - | 59 | - | 25 | - | 8 | - | - | 1 | - | 2 | 50 | - | - | 2 |
| **Massachusetts** | 10 | - | - | 2 | - | 2 | 22 | - | 225 | - | 16 | - | 214 | - | - | 2 | - | 2 | 68 | - | 112 | - | - | 2 | - | 2 | 214 | - | 121 | - |
| **Michigan** | 39 | - | - | 1 | 74 | - | - | 2 | 383 | - | - | 2 | 9 | - | - | 2 | - | 2 | 143 | - | 248 | - | - | 2 | - | 2 | 382 | - | 593 | - |
| **Minnesota** | 9 | - | - | 1 | 36 | - | 11 | - | 269 | - | 75 | - | 18 | - | - | 2 | - | 2 | 56 | - | 49 | - | - | 2 | - | 2 | 326 | - | 179 | - |
| **Mississippi** | 66 | - | - | 2 | - | 2 | 33 | - | 125 | - | 8 | - | - | 2 | - | 2 | - | 1 | 75 | - | 197 | - | - | 2 | - | 1 | - | 2 | 88 | - |
| **Missouri** | 35 | - | - | 2 | 5 | - | 101 | - | 88 | - | - | 2 | 5 | - | - | 2 | - | 2 | - | 2 | 111 | - | - | 2 | - | 2 | 380 | - | 87 | - |
| **Montana** | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 1 |
| **Nebraska** | 6 | - | - | 2 | 5 | - | - | 2 | 37 | - | - | 2 | - | 2 | - | 2 | - | 2 | 25 | - | 11 | - | - | 1 | 10 | - | 76 | - | - | 2 |
| **Nevada** | - | 2 | - | 2 | 19 | - | - | 2 | 251 | - | 8 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | 7 | - | 1 | - | - | 2 |
| **New Hampshire** | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 |
| **New Jersey** | 74 | - | - | 2 | - | 2 | 57 | - | 611 | - | 71 | - | 243 | - | - | 2 | - | 2 | 284 | - | 181 | - | - | 2 | - | 2 | 356 | - | 199 | - |
| **New Mexico** | - | 1 | - | 2 | - | 2 | - | 2 | 18 | - | 11 | - | - | 2 | - | 1 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 |
| **New York** | 49 | - | - | 2 | - | 2 | 36 | - | 617 | - | 15 | - | 248 | - | 31 | - | - | 2 | 136 | - | 112 | - | 3 | - | - | 2 | 272 | - | 192 | - |
| **North Carolina** | 132 | - | - | 1 | 55 | - | 50 | - | 422 | - | 17 | - | 58 | - | 79 | - | - | 2 | 286 | - | 787 | - | - | 2 | - | 2 | 184 | - | 88 | - |
| **North Dakota** | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | 3 | - | - | 2 | - | 1 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | 2 | - | - | 2 |
| **Ohio** | 301 | - | - | 2 | 152 | - | 174 | - | 609 | - | 80 | - | 93 | - | 49 | - | - | 2 | 366 | - | 710 | - | - | 2 | 18 | - | 924 | - | 935 | - |
| **Oklahoma** | 12 | - | - | 2 | 28 | - | 45 | - | 241 | - | 34 | - | 6 | - | - | 2 | - | 2 | 70 | - | 150 | - | - | 2 | - | 2 | 155 | - | 82 | - |
| **Oregon** | 1 | - | - | 2 | - | 2 | - | 2 | 280 | - | 18 | - | - | 2 | - | 2 | - | 2 | 4 | - | 7 | - | - | 2 | 39 | - | 12 | - | - | 2 |
| **Pennsylvania** | 123 | - | - | 2 | 48 | - | 51 | - | 686 | - | 42 | - | 153 | - | - | 2 | 17 | - | 340 | - | 265 | - | - | 2 | 26 | - | 400 | - | 693 | - |
| **Rhode Island** | - | 2 | - | 2 | - | 2 | 10 | - | - | 2 | 1 | - | 26 | - | - | 2 | - | 1 | 4 | - | - | 2 | - | 1 | - | 2 | 21 | - | - | 2 |
| **South Carolina** | 126 | - | - | 2 | 31 | - | 23 | - | 115 | - | - | 2 | 30 | - | 90 | - | - | 1 | 99 | - | 446 | - | - | 2 | - | 2 | 192 | - | 48 | - |
| **South Dakota** | - | 2 | - | 2 | - | 2 | - | 2 | 16 | - | - | 2 | - | 2 | - | 1 | - | 1 | 10 | - | - | 2 | - | 2 | - | 2 | 7 | - | 16 | - |
| **Tennessee** | 249 | - | - | 2 | 35 | - | 213 | - | 283 | - | 155 | - | - | 2 | - | 2 | - | 1 | 166 | - | 1152 | - | - | 1 | - | 2 | 370 | - | 144 | - |
| **Texas** | 300 | - | - | 2 | 180 | - | 492 | - | 1820 | - | 322 | - | 47 | - | - | 2 | - | 1 | 411 | - | 986 | - | - | 2 | 27 | - | 1292 | - | 659 | - |
| **Utah** | - | 2 | - | 2 | 16 | - | - | 2 | 123 | - | - | 2 | - | 2 | - | 1 | - | 1 | 4 | - | - | 2 | - | 2 | 65 | - | 14 | - | - | 2 |
| **Vermont** | - | 2 | - | 2 | - | 2 | - | 2 | 5 | - | - | 2 | 6 | - | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | 2 | - | - | 2 |
| **Virginia** | - | 2 | - | 2 | 10 | - | 21 | - | 200 | - | 39 | - | 24 | - | - | 2 | - | 2 | 83 | - | 259 | - | - | 2 | - | 2 | 160 | - | 98 | - |
| **Washington** | - | 2 | 34 | - | 28 | - | - | 2 | 330 | - | 7 | - | - | 2 | - | 1 | - | 1 | - | 2 | 17 | - | 6 | - | 87 | - | 43 | - | - | 2 |
| **West Virginia** | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | 5 | - | 18 | - | - | 1 | - | 2 | - | 2 | - | 2 |
| **Wisconsin** | 30 | - | - | 2 | 49 | - | 93 | - | 507 | - | 44 | - | - | 2 | - | 2 | - | 2 | 141 | - | 110 | - | - | 2 | 8 | - | 864 | - | 282 | - |
| **Wyoming** | - | 2 | - | 1 | - | 1 | - | 1 | - | 2 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 2 | - | 2 |
| **Total** | 3809 | - | 148 | - | 3106 | - | 3775 | - | 24374 | - | 2632 | - | 2596 | - | 1715 | - | 113 | - | 9291 | - | 11559 | - | 320 | - | 830 | - | 16948 | - | 9600 | - |

(Continued)

| | IA | | KS | | KY | | LA | | ME | | MD | | MA | | MI | | MN | | MS | | MO | | MT | | NE | | NV | | NH | |
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| | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S |
| **Alabama** | - | 2 | - | 2 | 100 | - | 42 | - | - | 2 | - | 2 | 16 | - | 30 | - | - | 2 | 45 | - | 74 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **Alaska** | - | 2 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Arizona** | 1 | - | 3 | - | - | 2 | - | 2 | - | 2 | 4 | - | 4 | - | - | 2 | 15 | - | - | 2 | - | 2 | - | 2 | - | 2 | 25 | - | - | 2 |
| **Arkansas** | 20 | - | - | 2 | 80 | - | 63 | - | - | 2 | - | 2 | 9 | - | 78 | - | 18 | - | 41 | - | 64 | - | - | 2 | 11 | - | - | 2 | - | 2 |
| **California** | 52 | - | 53 | - | 66 | - | 38 | - | - | 2 | 40 | - | 86 | - | 163 | - | 128 | - | 67 | - | 129 | - | 30 | - | 49 | - | 247 | - | - | 2 |
| **Colorado** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 6 | - | 14 | - | 7 | - | 37 | - | 1 | - | 19 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **Connecticut** | - | 2 | - | 2 | 20 | - | 8 | - | 11 | - | 5 | - | 204 | - | 31 | - | - | 2 | - | 2 | 11 | - | - | 2 | 8 | - | - | 2 | 84 | - |
| **Delaware** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 65 | - | 39 | - | - | 2 | - | 2 | 9 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 |
| **D.C** | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Florida** | 15 | - | 19 | - | 60 | - | 25 | - | - | 2 | 24 | - | 36 | - | 89 | - | 25 | - | 23 | - | 38 | - | - | 2 | 15 | - | 2 | - | 4 | - |
| **Georgia** | 34 | - | 13 | - | 82 | - | 98 | - | - | 2 | 59 | - | 57 | - | 223 | - | - | 2 | 152 | - | 108 | - | - | 2 | 11 | - | 10 | - | - | 2 |
| **Hawaii** | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Idaho** | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 7 | - | - | 1 | - | 2 | - | 2 |
| **Illinois** | 427 | - | 201 | - | - | 2 | 61 | - | - | 2 | 563 | - | 172 | - | 1463 | - | 544 | - | 88 | - | 599 | - | 19 | - | 208 | - | - | 2 | 11 | - |
| **Indiana** | 118 | - | 71 | - | 336 | - | 19 | - | 26 | - | 34 | - | 50 | - | 648 | - | 99 | - | 21 | - | 281 | - | - | 2 | 78 | - | 22 | - | 4 | - |
| **Iowa** | 813 | - | 66 | - | 164 | - | 37 | - | - | 2 | 7 | - | 18 | - | 228 | - | 223 | - | 32 | - | 285 | - | 21 | - | 133 | - | - | 2 | - | 2 |
| **Kansas** | 59 | - | 750 | - | 28 | - | - | 2 | - | 2 | - | 2 | 7 | - | 82 | - | 48 | - | - | 2 | 241 | - | - | 2 | 81 | - | - | 2 | - | 2 |
| **Kentucky** | - | 2 | 48 | - | 865 | - | 37 | - | - | 2 | - | 2 | - | 2 | 297 | - | 36 | - | 61 | - | 64 | - | - | 2 | 2 | - | 8 | - | 1 | - |
| **Louisiana** | 162 | - | 22 | - | 286 | - | 1386 | - | - | 2 | 6 | - | 62 | - | - | 2 | 74 | - | 258 | - | 50 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **Maine** | - | 2 | - | 2 | - | 2 | - | 2 | 135 | - | - | 2 | 36 | - | 13 | - | 6 | - | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | 12 | - |
| **Maryland** | - | 2 | 1 | - | 6 | - | - | 2 | - | 2 | 798 | - | 66 | - | 35 | - | - | 2 | - | 2 | 11 | - | - | 2 | - | 2 | - | 1 | - | 2 |
| **Massachusetts** | 7 | - | 21 | - | 51 | - | 8 | - | 235 | - | 88 | - | 2080 | - | 116 | - | 68 | - | 28 | - | 50 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **Michigan** | 33 | - | 36 | - | 125 | - | 46 | - | - | 2 | 62 | - | 93 | - | 4766 | - | 106 | - | 18 | - | 270 | - | - | 2 | 20 | - | - | 2 | 20 | - |
| **Minnesota** | 167 | - | 29 | - | - | 2 | - | 2 | - | 2 | 22 | - | - | 2 | 115 | - | 2019 | - | - | 2 | 157 | - | 9 | - | 107 | - | 5 | - | - | 2 |
| **Mississippi** | 15 | - | - | 2 | 42 | - | 75 | - | - | 2 | 3 | - | 26 | - | 35 | - | - | 2 | 668 | - | 43 | - | - | 2 | 59 | - | - | 2 | - | 2 |
| **Missouri** | 93 | - | 164 | - | 63 | - | - | 2 | - | 2 | 26 | - | 18 | - | 169 | - | 71 | - | - | 2 | 1482 | - | - | 2 | 40 | - | 1 | - | 6 | - |
| **Montana** | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 87 | - | - | 2 | - | 1 | - | 2 |
| **Nebraska** | 95 | - | 16 | - | 52 | - | - | 2 | - | 2 | - | 2 | 10 | - | 73 | - | 35 | - | 2 | - | 58 | - | - | 2 | 246 | - | - | 2 | - | 2 |
| **Nevada** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 146 | - | - | 2 |
| **New Hampshire** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 1 | - | - | 2 | 265 | - |
| **New Jersey** | 23 | - | 98 | - | 141 | - | 41 | - | 29 | - | 404 | - | 518 | - | 168 | - | 197 | - | 49 | - | 157 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **New Mexico** | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 1 |
| **New York** | 15 | - | 5 | - | 38 | - | 17 | - | - | 2 | 117 | - | 178 | - | 322 | - | 113 | - | 16 | - | 169 | - | 5 | - | - | 2 | - | 2 | 63 | - |
| **North Carolina** | 26 | - | 32 | - | 195 | - | 37 | - | 15 | - | 156 | - | - | 2 | 239 | - | 102 | - | 47 | - | 189 | - | 1 | - | 23 | - | - | 2 | - | 2 |
| **North Dakota** | 4 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 29 | - | - | 2 | - | 2 | 15 | - | - | 2 | - | 2 | - | 1 |
| **Ohio** | 231 | - | 166 | - | 714 | - | 55 | - | 39 | - | 190 | - | 255 | - | 1436 | - | 258 | - | 114 | - | 344 | - | 10 | - | 66 | - | 36 | - | 25 | - |
| **Oklahoma** | - | 2 | 58 | - | 13 | - | 10 | - | - | 2 | 24 | - | 8 | - | 143 | - | - | 2 | - | 2 | 105 | - | - | 2 | - | 2 | - | 2 | - | 2 |
| **Oregon** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 5 | - | 9 | - | - | 2 | 12 | - | 23 | - | - | 2 | 7 | - | - | 2 |
| **Pennsylvania** | 128 | - | 109 | - | 105 | - | 83 | - | 24 | - | 391 | - | 289 | - | 434 | - | 138 | - | 80 | - | 144 | - | - | 2 | 34 | - | - | 2 | 62 | - |
| **Rhode Island** | - | 2 | - | 2 | 1 | - | - | 2 | - | 2 | 5 | - | - | 2 | - | 2 | 1 | - | - | 2 | 3 | - | - | 2 | - | 2 | - | 2 | 13 | - |
| **South Carolina** | 5 | - | - | 2 | 114 | - | - | 2 | 56 | - | - | 2 | 51 | - | 197 | - | 61 | - | 48 | - | - | 2 | - | 2 | 10 | - | - | 2 | 56 | - |
| **South Dakota** | 7 | - | - | 2 | - | 2 | 2 | - | - | 2 | - | 2 | 1 | - | 21 | - | - | 2 | - | 1 | 10 | - | 2 | - | 11 | - | - | 2 | - | 2 |
| **Tennessee** | 111 | - | 36 | - | 267 | - | 103 | - | 50 | - | 41 | - | - | 2 | 635 | - | 100 | - | 206 | - | 155 | - | - | 2 | 25 | - | 15 | - | 14 | - |
| **Texas** | 214 | - | 262 | - | 278 | - | 282 | - | - | 2 | 91 | - | 183 | - | 790 | - | 201 | - | 280 | - | 405 | - | 69 | - | 122 | - | 138 | - | 53 | - |
| **Utah** | 3 | - | 4 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 7 | - | 5 | - | - | 2 | - | 2 | 7 | - | - | 2 | 13 | - | - | 2 |
| **Vermont** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 55 | - | 2 | - | 3 | - | 2 | - | - | 2 | - | 2 | - | 1 | - | 2 | 14 | - |
| **Virginia** | - | 2 | 54 | - | 156 | - | - | 2 | - | 2 | 172 | - | 96 | - | 191 | - | 27 | - | 7 | - | 57 | - | - | 2 | 4 | - | - | 2 | 67 | - |
| **Washington** | - | 2 | 15 | - | - | 2 | - | 2 | - | 2 | - | 2 | 10 | - | 6 | - | - | 2 | 6 | - | - | 2 | - | 2 | 7 | - | 10 | - | - | 2 |
| **West Virginia** | - | 2 | - | 2 | 29 | - | - | 2 | - | 2 | - | 2 | - | 2 | 128 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 |
| **Wisconsin** | 115 | - | 46 | - | 99 | - | 34 | - | - | 2 | 62 | - | 44 | - | 470 | - | 463 | - | - | 2 | 108 | - | - | 2 | 44 | - | 9 | - | - | 2 |
| **Wyoming** | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | - | 2 | - | 1 | - | 1 |
| **Total** | 3233 | - | 2687 | - | 5384 | - | 2803 | - | 1004 | - | 3710 | - | 5731 | - | 14241 | - | 5610 | - | 2743 | - | 6054 | - | 530 | - | 1639 | - | 1026 | - | 1312 | - |

*(Continued)*

| | NJ | | NM | | NY | | NC | | ND | | OH | | OK | | OR | | PA | | RI | | SC | | SD | | TN | | TX | | UT | |
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| | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S | V | S |
| **Alabama** | - | 2 | - | 2 | 98 | - | 74 | - | - | 2 | 393 | - | - | 2 | - | 2 | 149 | - | - | 2 | 48 | - | - | 2 | 205 | - | 326 | - | - | 2 |
| **Alaska** | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Arizona** | - | 2 | 26 | - | 10 | - | 5 | - | - | 2 | 8 | - | 5 | - | 21 | - | - | 2 | 1 | - | - | 2 | - | 2 | 4 | - | - | 2 | - | 2 |
| **Arkansas** | 46 | - | - | 2 | 29 | - | 102 | - | - | 2 | 95 | - | 140 | - | - | 2 | 63 | - | - | 2 | 114 | - | - | 2 | 79 | - | 355 | - | - | 2 |
| **California** | 265 | - | 32 | - | 322 | - | 303 | - | - | 2 | 312 | - | 58 | - | 395 | - | 200 | - | - | 2 | 26 | - | 8 | - | 119 | - | 699 | - | 204 | - |
| **Colorado** | 26 | - | 16 | - | 14 | - | 7 | - | - | 2 | - | 2 | 6 | - | 4 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 91 | - | 41 | - |
| **Connecticut** | 232 | - | - | 2 | 321 | - | 118 | - | - | 2 | - | 2 | - | 2 | - | 2 | 77 | - | - | 2 | 6 | - | - | 2 | - | 2 | 68 | - | - | 2 |
| **Delaware** | 108 | - | - | 2 | 64 | - | 21 | - | - | 1 | 44 | - | - | 2 | 7 | - | 37 | - | 21 | - | - | 2 | - | 1 | 8 | - | 29 | - | - | 1 |
| **D.C** | - | 1 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Florida** | - | 2 | 1 | - | 112 | - | 81 | - | - | 2 | 118 | - | - | 2 | - | 2 | 108 | - | 2 | - | 59 | - | - | 2 | 59 | - | 191 | - | - | 2 |
| **Georgia** | 78 | - | - | 2 | 82 | - | 497 | - | - | 2 | 387 | - | 33 | - | 12 | - | 197 | - | - | 2 | 444 | - | - | 2 | 434 | - | 407 | - | 31 | - |
| **Hawaii** | - | 2 | - | 1 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 |
| **Idaho** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 22 | - | - | 2 | - | 1 | - | 2 | - | 1 | - | 2 | 11 | - | 49 | - |
| **Illinois** | 534 | - | 12 | - | 374 | - | 330 | - | 50 | - | 1140 | - | 139 | - | 57 | - | 629 | - | - | 2 | 67 | - | 42 | - | 319 | - | 1451 | - | 85 | - |
| **Indiana** | 91 | - | - | 2 | 154 | - | 129 | - | - | 2 | 712 | - | 32 | - | 7 | - | 205 | - | - | 2 | - | 2 | - | 2 | 180 | - | 285 | - | - | 2 |
| **Iowa** | 35 | - | - | 2 | 64 | - | 96 | - | 73 | - | 177 | - | 26 | - | 34 | - | 82 | - | - | 2 | 29 | - | 55 | - | 72 | - | 194 | - | 6 | - |
| **Kansas** | 70 | - | 4 | - | - | 2 | 31 | - | - | 2 | 75 | - | 58 | - | 13 | - | 82 | - | - | 2 | 53 | - | - | 2 | 35 | - | 277 | - | 24 | - |
| **Kentucky** | 136 | - | - | 2 | 63 | - | 107 | - | - | 2 | 378 | - | 14 | - | 6 | - | 124 | - | - | 1 | - | 2 | - | 2 | 379 | - | 327 | - | - | 2 |
| **Louisiana** | 123 | - | - | 2 | 180 | - | 235 | - | 37 | - | 219 | - | 215 | - | 17 | - | 190 | - | - | 2 | 88 | - | - | 2 | 289 | - | 967 | - | - | 2 |
| **Maine** | - | 2 | - | 1 | - | 2 | - | 2 | - | 1 | 8 | - | - | 2 | - | 1 | 6 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 |
| **Maryland** | 98 | - | - | 2 | 160 | - | - | 2 | - | 2 | 41 | - | - | 2 | - | 2 | 199 | - | - | 2 | 10 | - | - | 1 | - | 2 | 32 | - | - | 2 |
| **Massachusetts** | 338 | - | - | 2 | 610 | - | 192 | - | - | 2 | 263 | - | 9 | - | 13 | - | 191 | - | 161 | - | - | 2 | - | 2 | 146 | - | 291 | - | 8 | - |
| **Michigan** | 89 | - | - | 2 | 74 | - | 130 | - | 3 | - | 818 | - | 26 | - | - | 2 | 172 | - | 2 | - | 37 | - | - | 2 | 208 | - | 335 | - | 9 | - |
| **Minnesota** | 83 | - | 6 | - | 64 | - | - | 2 | 57 | - | 43 | - | - | 2 | - | 2 | 75 | - | - | 2 | 7 | - | 61 | - | 45 | - | 146 | - | - | 2 |
| **Mississippi** | 41 | - | - | 2 | 33 | - | 68 | - | - | 2 | 200 | - | - | 2 | - | 2 | 62 | - | - | 2 | 16 | - | - | 1 | 143 | - | 176 | - | 1 | - |
| **Missouri** | 21 | - | - | 2 | - | 2 | 33 | - | - | 2 | 133 | - | 91 | - | 80 | - | 65 | - | - | 2 | 44 | - | 7 | - | 132 | - | 305 | - | 10 | - |
| **Montana** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 1 | - | - | 1 | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 |
| **Nebraska** | - | 2 | - | 2 | 24 | - | 13 | - | - | 2 | 48 | - | 4 | - | 3 | - | 45 | - | - | 1 | - | 2 | 14 | - | - | 2 | 32 | - | - | 2 |
| **Nevada** | - | 2 | 1 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 14 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | 13 | - |
| **New Hampshire** | 20 | - | - | 1 | 92 | - | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | 15 | - | 12 | - | - | 2 | - | 2 | 5 | - | - | 2 | - | 2 |
| **New Jersey** | 3689 | - | - | 2 | 1844 | - | 480 | - | - | 2 | 522 | - | 18 | - | - | 2 | 902 | - | - | 2 | - | 2 | - | 2 | 165 | - | 647 | - | 35 | - |
| **New Mexico** | - | 2 | 197 | - | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 | 33 | - | - | 2 |
| **New York** | 851 | - | - | 2 | 3489 | - | 181 | - | - | 2 | 515 | - | 5 | - | - | 2 | 1022 | - | 17 | - | - | 2 | - | 2 | 89 | - | 599 | - | 24 | - |
| **North Carolina** | 165 | - | - | 2 | - | 2 | 3294 | - | - | 2 | 474 | - | 64 | - | 82 | - | 313 | - | - | 2 | 1024 | - | - | 2 | 541 | - | 299 | - | 32 | - |
| **North Dakota** | - | 2 | - | 2 | - | 2 | - | 2 | 114 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 |
| **Ohio** | 525 | - | - | 2 | 778 | - | 671 | - | 12 | - | 5821 | - | 85 | - | 154 | - | 958 | - | - | 2 | 216 | - | 20 | - | 524 | - | 864 | - | 43 | - |
| **Oklahoma** | 36 | - | - | 2 | 69 | - | 18 | - | - | 2 | 155 | - | 456 | - | 33 | - | 76 | - | - | 2 | - | 2 | - | 2 | 45 | - | 292 | - | 8 | - |
| **Oregon** | - | 2 | 1 | - | 4 | - | 4 | - | - | 2 | - | 2 | - | 2 | 830 | - | 12 | - | - | 2 | - | 2 | - | 2 | 7 | - | 35 | - | - | 2 |
| **Pennsylvania** | 985 | - | 6 | - | 881 | - | 372 | - | 13 | - | 760 | - | 47 | - | 57 | - | 3970 | - | 61 | - | 95 | - | 6 | - | 240 | - | 422 | - | 30 | - |
| **Rhode Island** | 51 | - | - | 2 | - | 2 | - | 2 | - | 1 | 21 | - | - | 2 | - | 2 | 34 | - | - | 2 | - | 2 | - | 2 | - | 2 | 20 | - | - | 2 |
| **South Carolina** | 67 | - | - | 2 | 190 | - | 680 | - | - | 2 | 290 | - | - | 2 | - | 2 | 124 | - | 6 | - | 1893 | - | - | 2 | 119 | - | 248 | - | - | 2 |
| **South Dakota** | - | 2 | - | 2 | 13 | - | 8 | - | - | 2 | - | 2 | - | 2 | 2 | - | 6 | - | - | 2 | 8 | - | 121 | - | - | 2 | 21 | - | - | 2 |
| **Tennessee** | 155 | - | - | 2 | 313 | - | 225 | - | - | 2 | 520 | - | 37 | - | - | 2 | 227 | - | 54 | - | 208 | - | - | 2 | 1669 | - | 540 | - | 31 | - |
| **Texas** | 503 | - | 207 | - | 382 | - | 628 | - | - | 2 | 987 | - | 456 | - | 166 | - | 674 | - | 51 | - | 375 | - | - | 2 | 588 | - | 13169 | - | 120 | - |
| **Utah** | - | 2 | 3 | - | 7 | - | 3 | - | - | 2 | 13 | - | 3 | - | 20 | - | 3 | - | - | 1 | - | 2 | - | 2 | 1 | - | 36 | - | 545 | - |
| **Vermont** | 13 | - | - | 1 | 53 | - | - | 2 | - | 1 | 23 | - | - | 2 | - | 2 | 27 | - | - | 2 | - | 2 | - | 1 | - | 2 | 9 | - | - | 2 |
| **Virginia** | 283 | - | - | 2 | 263 | - | 243 | - | - | 2 | 423 | - | 11 | - | - | 2 | 317 | - | - | 2 | 135 | - | 5 | - | - | 2 | 254 | - | - | 2 |
| **Washington** | 16 | - | - | 2 | 14 | - | 10 | - | - | 2 | 40 | - | - | 2 | 294 | - | 25 | - | - | 2 | - | 2 | - | 2 | - | 2 | 36 | - | 49 | - |
| **West Virginia** | - | 2 | - | 2 | - | 2 | 36 | - | - | 1 | 232 | - | - | 1 | - | 2 | 166 | - | - | 1 | - | 2 | - | 1 | 23 | - | - | 2 | - | 2 |
| **Wisconsin** | 107 | - | - | 2 | - | 2 | 102 | - | 21 | - | 422 | - | - | 2 | 11 | - | 185 | - | - | 2 | 46 | - | - | 2 | 199 | - | 267 | - | 33 | - |
| **Wyoming** | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 | - | 2 | - | 2 | - | 1 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 |
| **Total** | 10216 | - | 670 | - | 13047 | - | 9723 | - | 626 | - | 17050 | - | 2281 | - | 2752 | - | 12099 | - | 1001 | - | 6025 | - | 470 | - | 7608 | - | 24996 | - | 1825 | - |

*(Continued)*

| | VM | | VA | | WA | | WV | | WI | | WY | | TOi | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V | S | V | S | V | S | V | S | V | S | V | S | V | S |
| **Alabama** | - | 2 | 22 | - | 4 | - | - | 2 | 19 | - | - | 2 | 3869 | - |
| **Alaska** | - | 1 | - | 1 | - | 2 | - | 1 | - | 1 | - | 1 | 79 | - |
| **Arizona** | - | 2 | - | 2 | 15 | - | - | 2 | 11 | - | - | 2 | 1789 | - |
| **Arkansas** | 1 | - | 3 | - | 15 | - | - | 2 | 19 | - | - | 2 | 3114 | - |
| **California** | 7 | - | 67 | - | 585 | - | 5 | - | 141 | - | 21 | - | 19867 | - |
| **Colorado** | - | 2 | - | 2 | 34 | - | - | 1 | - | 2 | 27 | - | 1911 | - |
| **Connecticut** | 47 | - | - | 2 | - | 2 | - | 2 | 34 | - | - | 2 | 2768 | - |
| **Delaware** | - | 2 | - | 2 | 4 | - | - | 2 | 30 | - | - | 1 | 791 | - |
| **D.C** | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 2 |
| **Florida** | - | 2 | 32 | - | 21 | - | 4 | - | 23 | - | - | 1 | 6385 | - |
| **Georgia** | - | 1 | 108 | - | 24 | - | - | 2 | 179 | - | - | 2 | 9658 | - |
| **Hawaii** | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | - | 1 | 188 | - |
| **Idaho** | - | 2 | - | 2 | 36 | - | - | 1 | - | 2 | 5 | - | 557 | - |
| **Illinois** | - | 2 | 127 | - | 146 | - | - | 2 | 896 | - | - | 2 | 22300 | - |
| **Indiana** | - | 2 | - | 2 | 40 | - | 15 | - | 224 | - | - | 2 | 7732 | - |
| **Iowa** | - | 2 | 55 | - | 54 | - | 3 | - | 185 | - | - | 2 | 4148 | - |
| **Kansas** | - | 2 | 11 | - | - | 2 | 7 | - | 49 | - | 4 | - | 3140 | - |
| **Kentucky** | - | 2 | 64 | - | 12 | - | 11 | - | 46 | - | - | 1 | 4436 | - |
| **Louisiana** | - | 2 | 192 | - | - | 2 | - | 2 | 121 | - | - | 2 | 7343 | - |
| **Maine** | - | 2 | - | 2 | - | 2 | - | 1 | 14 | - | - | 2 | 479 | - |
| **Maryland** | - | 2 | 148 | - | 3 | - | - | 2 | - | 2 | - | 2 | 2165 | - |
| **Massachusetts** | 123 | - | 85 | - | 34 | - | - | 2 | 85 | - | - | 2 | 6765 | - |
| **Michigan** | - | 2 | 68 | - | - | 2 | 5 | - | 135 | - | - | 2 | 9923 | - |
| **Minnesota** | - | 2 | 22 | - | 35 | - | - | 2 | 242 | - | - | 2 | 5073 | - |
| **Mississippi** | - | 2 | 32 | - | 16 | - | - | 2 | - | 2 | - | 2 | 2993 | - |
| **Missouri** | - | 2 | - | 2 | 35 | - | - | 2 | 55 | - | - | 1 | 4329 | - |
| **Montana** | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | 16 | - | 143 | - |
| **Nebraska** | - | 1 | - | 2 | - | 2 | - | 2 | 48 | - | - | 2 | 1231 | - |
| **Nevada** | - | 2 | - | 2 | 17 | - | - | 2 | - | 2 | - | 2 | 554 | - |
| **New Hampshire** | 100 | - | - | 2 | - | 2 | - | 2 | 9 | - | - | 1 | 1284 | - |
| **New Jersey** | 28 | - | 225 | - | 74 | - | 17 | - | 108 | - | - | 2 | 13705 | - |
| **New Mexico** | - | 1 | - | 1 | - | 2 | - | 1 | - | 2 | - | 2 | 311 | - |
| **New York** | 45 | - | 142 | - | 74 | - | 20 | - | 148 | - | - | 2 | 10325 | - |
| **North Carolina** | 15 | - | 479 | - | - | 2 | 93 | - | 85 | - | - | 2 | 11207 | - |
| **North Dakota** | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | - | 2 | 216 | - |
| **Ohio** | - | 2 | 261 | - | 110 | - | 544 | - | 354 | - | 18 | - | 20427 | - |
| **Oklahoma** | - | 2 | 13 | - | 34 | - | - | 2 | 149 | - | - | 2 | 2775 | - |
| **Oregon** | - | 2 | - | 2 | 443 | - | - | 2 | - | 2 | - | 2 | 1978 | - |
| **Pennsylvania** | 19 | - | 244 | - | 51 | - | 125 | - | 164 | - | - | 2 | 14060 | - |
| **Rhode Island** | - | 2 | - | 2 | - | 2 | - | 1 | - | 2 | - | 1 | 953 | - |
| **South Carolina** | 23 | - | 109 | - | - | 2 | - | 2 | 85 | - | - | 2 | 6012 | - |
| **South Dakota** | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 | 7 | - | 412 | - |
| **Tennessee** | 3 | - | - | 2 | 112 | - | 17 | - | 128 | - | - | 2 | 9947 | - |
| **Texas** | - | 2 | 373 | - | 229 | - | 88 | - | 210 | - | - | 2 | 29313 | - |
| **Utah** | - | 2 | 5 | - | 22 | - | - | 2 | 7 | - | 4 | - | 1014 | - |
| **Vermont** | 74 | - | - | 2 | - | 2 | - | 2 | - | 2 | - | 1 | 377 | - |
| **Virginia** | - | 2 | 1524 | - | 26 | - | 52 | - | 95 | - | - | 2 | 6007 | - |
| **Washington** | - | 2 | 6 | - | 1749 | - | - | 2 | - | 2 | - | 2 | 3126 | - |
| **West Virginia** | - | 1 | 60 | - | 97 | - | 485 | - | 19 | - | - | 1 | 2582 | - |
| **Wisconsin** | - | 2 | 129 | - | 86 | - | - | 2 | 2444 | - | - | 2 | 8769 | - |
| **Wyoming** | - | 2 | - | 2 | - | 1 | - | 2 | - | 2 | - | 2 | - | 2 |
| **Total** | 703 | - | 5812 | - | 4507 | - | 1832 | - | 6713 | - | 352 | - | 278832 | |

**< NOTE >**

-V=Value (Mil $)

-S=Symbol

1: represent zero or less than 1unit of measure

2: data do not meet publication standards due to high sampling variability or other reasons

3: denotes figures withheld to avoid disclosing data for individual company

-Source: Bureau of Transportation Statistics and U.S. Census

# Potential Economic Impact of Commercial Offshore Aquaculture in the Gulf of Mexico

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## Introduction

Economic benefits from aquaculture production accrue not only to those directly involved in the industry but contribute to increased employment and revenue of the entire region through multiplier effects. Aquaculture can also supplement domestic fisheries, increase seafood production and provide stability for the seafood industry. A successful approach to solving many current domestic fishery problems is through the development of an intensive aquaculture program in the United States. While farmed seafood contributes more than 25% by weight to world seafood production, U.S. production is less than 3% of world aquaculture production. Coastal and offshore aquaculture frequently involves new species, product forms and production technologies. During the last decade, several species have been raised along the Gulf of Mexico including catfish, baitfish, gamefish, crawfish, red drum, hybrid striped bass, tilapia, alligator, freshwater prawn, oyster and carp.

The Gulf of Mexico commercial offshore aquaculture (COAC) industry would include the production, processing and distribution sectors of aquaculture species in these waters. The use of cages to grow food fish in the Gulf of Mexico waters had been a subject to recent research efforts and commercial ventures (GMFMC, 2004). SeaFish Mariculture, LLC (SFM) successfully raised red drum from 3-in fingerlings to market-size fish in less than 12 months in a fishfarming research project off Freefort, Texas (GMFMC, 2004). The Gulf of Mexico Offshore Aquaculture Consortium (OAC) attempted to grow cobia from fingerlings to market-size in an experimental cage 40 km off Pascagoula, Mississippi (Bridger, et al., 2003).

The overall goal of this paper is to estimate the potential economic impact of the establishment of economically viable commercial offshore aquaculture production systems in the Gulf of Mexico. Specifically, it aims to estimate the over-all economic impact of the initial establishment and operation of COAPS in the Gulf of Mexico; and determine the economic sectors with the strongest linkage to these new offshore aquaculture production systems.

## Materials and Methods

The potential economic impact of the COAC industry was estimated by using IMPLAN Professional 2.0 Software and the 2000 Gulf of Mexico States IMPLAN data files, including Florida, Alabama, Mississippi, Louisiana and Texas. These impact planning software and data files facilitated the estimation of economic impacts with the use of the most appropriate multipliers (MIG, 1999). Two series of economic impact estimates were prepared for the COAC industry. The first series of estimates included those associated with the initial investment expenditures that would be incurred during the establishment or construction year. The second series of estimates covered those annual expenditures that would be incurred in operating the commercial offshore aquaculture production system (COAPS). Offshore aquaculture production would also enhance both commercial and recreational fishing in the nearby waters. Additional production of the candidate species would also increase both processing and distribution activities in both existing and new processing and distribution plants.

The production sector of the COAC industry would be consisted of the culture of saltwater aquaculture species in offshore waters of the Gulf. Posadas and Bridger (2003) developed a hypothetical COAPS based on current information on offshore grow-out technology in the Gulf. The candidate species include cobia (*Rachycentron canadum*), red snapper (*Lutjanus campechanus*), and red drum (*Sciaenops ocellatus*). The production system consists of an aquaculture service vehicle (ASV) and Ocean Spar Sea Station cages. The ASV is a mobile offshore support facility which can be used to adjust the deployment of the sea cages. The 3000-$m^3$ cages are deployed in offshore waters, at least 24 m deep, and assumed to hold 20-30 $kg/m^3$ of market-size fish. An economically viable hypothetical COAPS consisted of 12 cages which would require an initial fixed investment of $3.85 M.

The COAPS sector was represented by the “Miscellaneous livestock ” IMPLAN sector 9 which corresponded to the 1987 Bureau of Economic Analysis (BEA) Standard Industrial Classification (SIC) codes 0271 and 0272 (MIG, Inc., 1999). The commercial seafood processing sector involved plants engaged in primary wholesale and processing activities. IMPLAN sector “Prepared Fresh or Frozen Fish or Seafood, 98" corresponded to the 1987 BEA-SIC code 2092 (MIG, Inc., 1999). Commercial harvesting is represented by IMPLAN sector 25 which corresponded to the 1987 Bureau of Economic Analysis (BEA) Standard Industrial Classification (SIC) code 0910 (MIG, Inc., 1999). The ex-vessel values of the Gulf commercial fishing sector were retrieved from the NMFS (2004) website.

Extrapolating a potential COAC industry from these hypothetical COAP models presents is a big leap forward to the realm of uncertainty. Several key economic and marketing issues need to be addressed when projecting an industry-wide economic impact of COAC with more than one COAPS consisting of 12-cages. There are no published inventory of offshore areas suitable for COAPS which do not have conflicts with current and future users of these marine resources. Appropriate technology for offshore growout - stocking, feeding, and harvesting - still need to be developed and tested under extreme remote conditions prevailing in the Gulf growing waters. There is not enough information that can be used to measure the reaction of the domestic market to expansion in the supply of the cultured species arising from the establishment of COAPS and imports from foreign producers. The logistics of supplying COAPS with manpower and material to sustain day-to-day operations still remain to be developed and tested under Gulf conditions. Public perceptions, legal and political mind-sets, and environmental constraints associated with COAPS have to be addressed in order to make the investment climate more favorable. Current regulations affecting the harvesting, production and marketing of the candidate species in both state and federal waters are major constraints every grower, lender or investor has to deal with before deciding to enter into this highly uncertain venture.

## Results and Discussion

### Impact of Initial Investment in a Single COAPS

The initial investment expenditures in setting-up a single COAPS with 12 cages that would be incurred during its establishment year would generate additional output of economic goods and services valued at $6.84 million (Table 1). Associated with this added economic activity would be an increase in the derived demand for 197 workers. The expected increase in labor income, which consists of employee compensation and proprietor's income, would reach $2.17 million. Indirect business tax collections are estimated at $210,870. Federal income tax collections would include $231,000 from personal income taxation, and $59,000 from corporate income taxation.

### Annual Impact of Operating a Single COAPS

Single COAPs with 12 cages stocked with the candidate species would require different levels of input - primarily fingerlings and feed (Table 2). Annual fish production would be 1.08 M mt for all three species. Differences in ex-vessel prices would generate varying levels of annual fish sales, cobia - $5.67 M, red snapper - $5.94 M, and red drum - $5.13 M..

With the annual fish sales expected from the economically feasible single COAPS with 12 cages, the economic impact to the Gulf regional economy were measured by using four indicators: output of goods and services, jobs, labor income, and indirect business taxes. Using the same 2000 Gulf IMPLAN model, additional output produced would range from $9.1 M to $10.2 M. The number of jobs created would be between 262-289 positions. The single COAPS would generate additional proprietors income and employee compensation ranging from $2.9 M to $3.2 M. Annual indirect business taxes associated with the added output produced by a single COAPS would amount to at least $281,000. This tax collection does not include personal income taxation that could be collected from employment and ownership of these COAPS. Federal and state personal income tax collections from households would amount to $340,000 and $11,000, respectively. Tax collections from corporate profits would reach $87,000 and $4,000 for federal and state taxing authorities, respectively.

### Impact of Current Commercial Fish Harvesting

Commercial harvesting of the candidate species is limited by state and federal regulations. Recent domestic commercial landings valued at ex-vessel prices exceeded $10 million (Figure 3). Using the same 2000 Gulf IMPLAN model, the commercial landings valued at $12.4 million, if all landed in the Gulf, could have created an economic impact in the region amounting to $20.1 million output of goods and services (Table 4). A total of 628 jobs could have been created and a combined income of workers and proprietors could reach $10.3 million. Business establishments would also remit indirect business taxes amounting to $0.86 million.

### Impact of Current Commercial Foodfish Processing

The 64 Gulf processing plants engaged in the primary processing and wholesaling of foodfish handled a total plant-gate value of foodfish products amounting to $52.7 million in 2000 (NMFS, 2004). By using the same 2000 Gulf IMPLAN model, total economic impact of commercial foodfish processing reached $80.8 million (Table 5). This sector also provided 769 jobs and generated $17.6 million labor income to the region. Indirect business taxes collected from this sector amounted to $1.3 million.

### Sectoral Economic Linkages

The direct effects created by the establishment and operation of a single COAPS with 12 cages would generate indirect and induced effects. Indirect effects consist of the inter-industry effects of the input-output analysis. Induced effects consist of the impact of household expenditures in input-output analysis. (MIG, Inc., 1999). The sum of the direct, indirect, and induced effects is equal to the total economic impact measured in terms of output ($), jobs, labor income ($), and tax collections ($).

The indirect or inter-industry linkages would mostly occur among the agriculture (27%), manufacturing (23%), trade (14%), and transportation, communication, and public utilities (TCPU = 14%) sectors (Figure 1). Additional indirect linkages could be expected from the services (8%), and finance, insurance, and real estate (FIRE = 7%) sectors.The induced effects associated with increased household expenditures would be mostly observed among the services (30%), trade (24%), FIRE (23%) sectors (Figure 2). The manufacturing and TCPU sectors would share some of the induced effects (9%) generated by added household spending.

## Conclusion

The economic impact of an emerging offshore aquaculture industry and existing fish harvesting and processing industry on the regional economy was estimated by using IMPLAN. The annual economic impact to the Gulf of Mexico region of a single offshore aquaculture production system consisting of 12 cages would consist of additional economic output ranging from $9.1M to $10.2 M. In comparison, current commercial harvesting of the three candidate species in the Gulf of Mexico, which are limited by state and federal regulations, created an economic impact in the region amounting to $20.1 M . The subsequent primary processing and wholesaling of all foodfish species in the Gulf of Mexico created a total economic impact reaching $80.8 M.

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TABLE 1. Summary of economic impact of initial investment expenditures on a single COAPS using 12 cages incurred during the establishment year

| Item | Output ($ x 10^6) | Employment (jobs) | Labor Income ($ x 10^6) | Indirect Business Taxes ($ x 10^3) |
|---|---|---|---|---|
| Direct | 3.85 | 156 | 1.17 | 46.33 |
| Indirect | 1.59 | 24 | 0.49 | 74.67 |
| Induced | 1.40 | 17 | 0.51 | 89.86 |
| Total | 6.84 | 197 | 2.17 | 210.87 |

TABLE 2. Inputs and outputs in an economically viable COAPS using 12 cages stocked with candidate species under enhanced market and improved growth conditions. (Posadas and Bridger, 2003).

| Item | Unit | COBIA | SNAPPER | DRUM |
|---|---|---|---|---|
| Stocking density | fish/m$^3$ | 5.70 | 66.74 | 33.06 |
| Stocking size | g/fish | 10.00 | 10.00 | 10.00 |
| Improved growth rate | g/mo | 729.00 | 46.00 | 100.00 |
| Annual fingerling requirements | 1,000 pc | 205.20 | 2,402.64 | 1,190.16 |
| Average fingerling cost | $/1000 pc | 750.00 | 750.00 | 750.00 |
| Annual fingerling costs | $ x 10$^6$ | 0.15 | 1.80 | 0.89 |
| Average feed cost, bulk-rate | $/mt | 705.48 | 705.48 | 705.48 |
| Annual feed requirements | 1,000 mt | 1.62 | 1.62 | 1.62 |
| Annual feed costs, bulk-rate | $ x 10$^6$ | 1.14 | 1.14 | 1.14 |
| Annual fish production, heads-on | 1,000 mt | 1.08 | 1.08 | 1.08 |
| Enhanced ex-vessel price, heads-on | $/kg | 5.25 | 5.50 | 4.75 |
| Improved harvest size, heads-on | kg/fish | 6.57 | 0.56 | 1.21 |
| Enhanced annual fish sales, gross | $ x 10$^6$ | 5.67 | 5.94 | 5.13 |

TABLE 3. Summary of annual economic impact of a single COAPS using 12 cages stocked with candidate species under enhanced market and improved growth conditions

| Item | Output ( $ x $10^6$) | | | Employment (jobs) | | | Labor Income ($ x $10^6$) | | | Indirect Business Taxes ($ x $10^3$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | COBIA | SNAPPER | DRUM | COBIA | SNAPPER | DRUM | COBIA | SNAPPER | DRUM | COBIA | SNAPPER | DRUM |
| Direct | 5.7 | 5.7 | 5.1 | 229 | 232 | 208 | 1.7 | 1.7 | 1.6 | 68.1 | 69.0 | 61.7 |
| Indirect | 2.3 | 2.4 | 2.1 | 35 | 36 | 32 | 0.7 | 0.7 | 0.6 | 109.8 | 111.2 | 99.5 |
| Induced | 2.1 | 2.1 | 1.9 | 25 | 25 | 22 | 0.7 | 0.8 | 0.7 | 132.2 | 133.8 | 119.7 |
| Total | 10.1 | 10.2 | 9.1 | 289 | 293 | 262 | 3.2 | 3.2 | 2.9 | 310.2 | 314.0 | 281.0 |

TABLE 4. Summary of annual economic impact of combined commercial fish harvesting of cobia, red snapper, and red drum in the Gulf of Mexico, 2000

| Item | Output ($ x $10^6$) | Employment (jobs) | Labor Income ($ x $10^6$) | Indirect Business Taxes ($ x $10^3$) |
|---|---|---|---|---|
| Direct | 12.4 | 586 | 7.6 | 389.9 |
| Indirect | 0.9 | 8 | 0.3 | 33.6 |
| Induced | 6.7 | 34 | 2.5 | 433.2 |
| Total | 20.1 | 628 | 10.3 | 856.7 |

TABLE 5. Summary of annual economic impact of commercial foodfish processing in the Gulf of Mexico, 2000

| Item | Output ($ x $10^6$) | Employment (jobs) | Labor Income ($ x $10^6$) | Indirect Business Taxes ($ x $10^3$) |
|---|---|---|---|---|
| Direct | 52.7 | 338 | 7.3 | 318.1 |
| Indirect | 17.0 | 297 | 6.3 | 1,009.4 |
| Induced | 11.1 | 133 | 4.0 | 0.7 |
| Total | 80.8 | 769 | 17.6 | 1,328.1 |

# General Equilibrium Assessment of Regional Climate Change Policy

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## Introduction

Analyses of climate change mitigation strategies generally concentrate on national policies and estimate economic impacts at the national level. However, there has been growing interest in developing climate policy at the state and regional levels in the U.S., especially the Northeast. Given that many U.S. states emit larger quantities of GHGs than entire countries (CCAP, 2002),[2] there is potential for substantial GHG emission reductions at the subnational level. In addition, many viable strategies at the subnational level have been identified, and numerous mitigation policies are currently in place (Pew Center; 2004; Rabe, 2002; CCAP, 2002).

Although these actions are likely to generate environmental benefits, the inherently limited scope and possible lack of integration associated with subnational policies may result in inefficiencies relative to more comprehensive policies covering more categories of emission sources, more GHGs, and larger geographical areas.[3] This paper evaluates the economic consequences of addressing global climate change through subnational policies using the Applied Dynamic Analysis of the Global Economy (ADAGE) model, a computable general equilibrium (CGE) modeling system. The model is used to assess the economic impacts of reducing GHG emissions through unilateral cap-and-trade policies, applied to one or more regions of the United States. In addition to regional coverage, we estimate the effects of varying the scope of the policy in terms of emission sources and GHGs included in the trading program. Our results highlight implications for energy markets and other key sectors most directly affected by GHG emission limits, along with distributional effects on various types of households. Across all scenarios analyzed, we find costs of hitting a given mitigation target fall dramatically as policies are expanded to be more comprehensive.

## Sub-National Climate Policy

State and local governments in the U.S. have been developing climate change policy for over a decade, although their efforts have intensified in recent years. Several states passed legislation or issued executive orders endorsing initial steps to mitigate climate change in the late 1980s, although these early initiatives were largely symbolic expressions of concern that did not require specific actions (Rabe, 2002). In the early to mid-1990s, most states began producing detailed

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[2] For instance, as of 1998, only China, the Former Soviet Union, Japan, India, and Germany emitted more $CO_2$ than Texas. California, Ohio, Pennsylvania, Florida, Illinois, Michigan, New York, Georgia, and New Jersey each emit more $CO_2$ than industrialized countries such as Belgium, Austria, Denmark, Sweden, and Norway (CCAP, 2002).

[3] Similar inefficiencies have been found at the international level for climate change mitigation policies. See, for example, the collection of CGE analyses in the Kyoto Special Issue of the Energy Journal (Weyant, 1999).

inventories of their GHG sources and emission trends, which have served as the foundation for state policy development in recent years. Since January 2000, approximately one-third of states have approved new legislation and/or instituted executive orders expressly intended to reduce GHG emissions and many other states are considering similar actions (Rabe, 2002). In addition, cities such as Seattle, Washington; Austin, Texas; Portland, Oregon; and Salt Lake City, Utah have adopted specific goals for GHG emission reduction. In many cases, the focus has been on policies that integrate climate change mitigation with other goals such as improved air quality and reductions in traffic congestion (CCAP, 2002).

Few states have set quantitative goals for reducing total GHG emissions, although this is beginning to change. Instead, states have generally chosen to focus on a specific set of sources that will be subject to control, typically in the energy or transportation sectors.[4] An exception to this at a regional level is in the Northeast U.S., where multiple states are exploring the prospects for regional coordination and cooperation to achieve specific numeric targets for overall GHG emission reductions. A coalition of New England Governors and Eastern Canadian Premiers proposed a Climate Change Action Plan in 2001 that calls for each Governor and Premier to develop and implement a plan that reduces their state's GHG emissions to1990 levels by 2010 and lower them an additional 10 percent by 2020 (NEG/ECP, 2001). Maine passed the first state law setting specific targets and timelines for GHG emission reductions in June 2003. These new rules direct the state to develop a climate action plan by summer 2004 with a goal of reducing GHG emissions by levels consistent with those in the regional Climate Change Action Plan. More recently, ten governors in the Northeast U.S. have begun a plan to develop a regional market-based trading program for $CO_2$ permits. Our policy simulations using the ADAGE model are based on scenarios similar to these plans under development in the Northeast.

## Adage Model Description[5]

The ADAGE model is a dynamic, intertemporally-optimizing CGE model capable of investigating economic policies at the international, national, U.S. regional and U.S. state levels (see Figure 1). CGE models such as ADAGE combine economic theory and empirical data to estimate how policies' effects will ripple though the economy, while accounting for all interactions among firms and consumers. Among these economic linkages are: how firms purchase material inputs from other businesses and factors of production (labor, capital, and natural resources) from households in order to produce goods, how consumers receive income from factor sales and buy goods from firms, and how traded goods flow among regions. ADAGE solves in five-year intervals from 2005 to 2050 and can be used to explore how the economy may respond to policy announcements and identify transition paths to new economic equilibria.

ADAGE is solved as a mixed complementarity problem (MCP) with the GAMS language (Generalized Algebraic Modeling System; Brooke et al. [1998]) using MPSGE software

[4] Examples include electricity sector standards and caps; renewable portfolio standards (these require utilities to provide a certain amount or percentage of renewable power); tax incentives for low-GHG emission vehicle and fuel use; and residential and commercial tax incentives for energy efficiency and renewable energy.

[5] See Ross (forthcoming) for additional details on data sources, model structure, and parameter estimates.

(Mathematical Programming Subsystem for General Equilibrium; Rutherford [1999]) to aid in programming. The GAMS/PATH solver is used to solve the MCP equations generated by the MPSGE software.

In general, computational constraints limit the total size of nonlinear, intertemporally-optimizing CGE models such as ADAGE. Thus, for this analysis of climate-change mitigation policies with multiple U.S. regions, the data were aggregated to five primary energy industries (coal, crude oil, electricity [fossil and non-fossil], natural gas, and refined petroleum) and five other major industry groupings (agriculture, energy-intensive manufacturing, other manufacturing, services, and transportation). ADAGE, however, is fully flexible across regions and industries contained in its databases and can be re-aggregated for particular policy investigations to include specific regions and industries of interest (where the total number of regions and industries is constrained by computational considerations).

ADAGE uses the classical Arrow-Debreu general equilibrium framework wherein households maximize utility across all time periods subject to budget constraints, and perfectly competitive firms maximize profits subject to technology constraints. The model structure, in which households are assumed to have perfect foresight, allows agents to modify behavior in anticipation of future policy changes, unlike dynamic recursive models that assume agents do not react until a policy has been implemented. Nested constant-elasticity-of-substitution (CES) equations characterize firm and household behaviors, as well as options for technological improvements. Along with the underlying data, the nesting structures and associated substitution elasticities define current production technologies and possible alternatives. At equilibrium solution prices, all markets must clear – implying that: every commodity produced is purchased by firms or consumers within a region or exported; prices of goods reflect all costs of production; households receive payments for their productive factors and this income equals consumer expenditures; and, in aggregate, supplies of goods and factors equals demand.

**Figure 1. The ADAGE Model: Integrated Framework of Connected Modules**

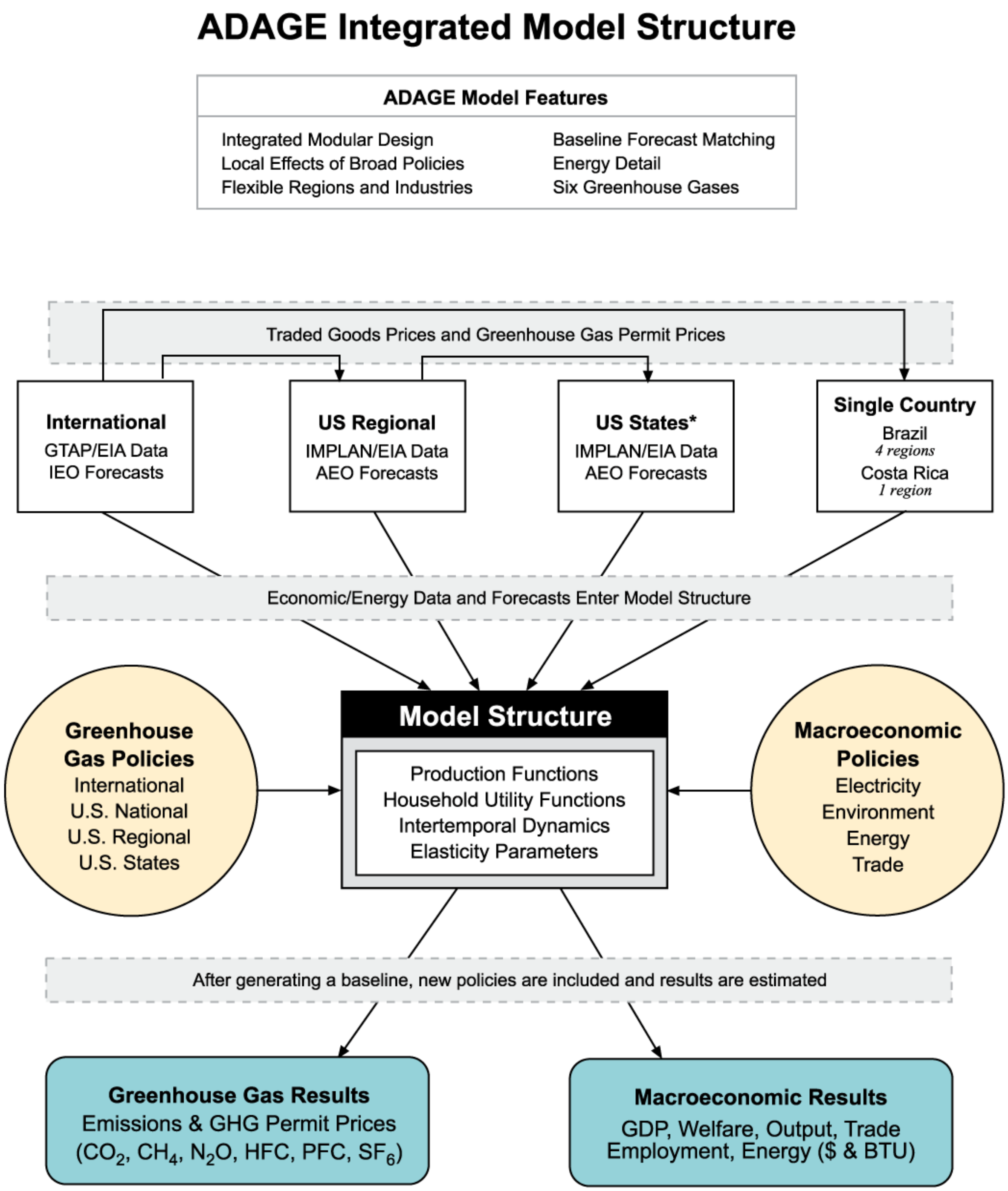
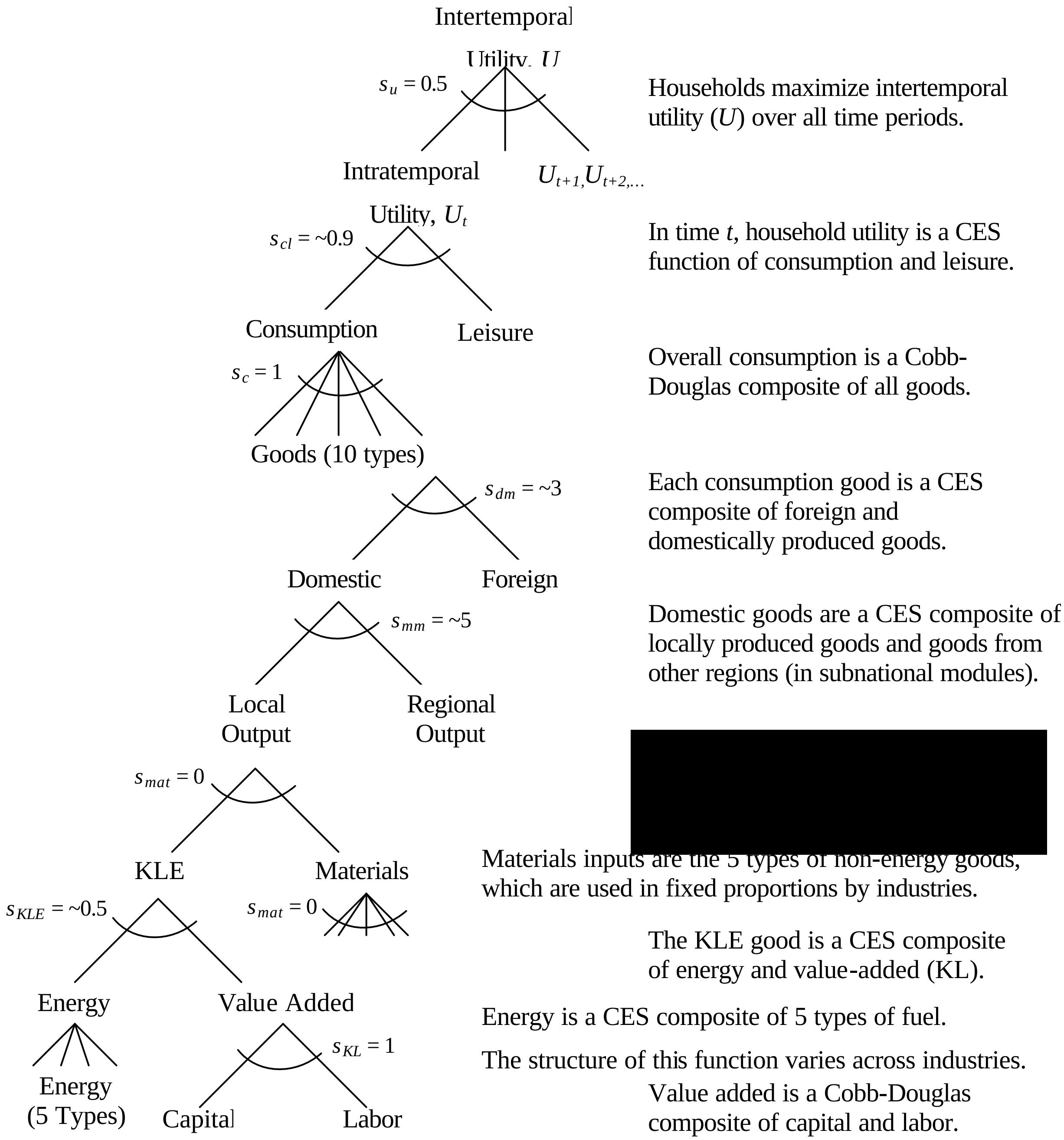


Figure 2 illustrates the general ADAGE framework and gives a broad characterization of the model and associated elasticities of substitution between goods and factors (noted by $s$). At the top level, households in each region maximize intertemporal utility across all time periods in the model subject to budget constraints, which are based on endowments of factors of production (labor, capital, natural resources, and land inputs to agricultural production). Factor prices are equal to the marginal revenue received by firms from employing an additional unit of that factor, and the values of factors owned by households depend on factor use implied by production within each region. Income from sales of these productive factors is allocated to purchases of consumption goods and investments to generate capital goods for future production. Following standard conventions of CGE models, the factors of production owned by households are assumed to be intersectorally mobile within a region, but migration of productive factors is not allowed across regions. This assumption is necessary to calculate changes in utility for representative households located in each region. ADAGE assumes that ownership of natural resources and capital embodied in nonfossil electricity generation is spread across the United States through capital markets. Within each time period, intratemporal household utility is a function of consumption and leisure. The elasticity of substitution between consumption goods and leisure, $s_{cl}$, indicates how willing households are to trade off leisure time for consumption and is controlled by labor supply elasticities. Below these utility functions, individual consumption goods are formed from domestic goods, goods from other regions within the U.S., and foreign imports. Goods and services are assumed to be composite, differentiated "Armington" goods made up of locally manufactured commodities and imported goods (Armington, 1969).[6]

At the bottom of Figure 2, production technologies are specified that control how inputs can be substituted for each other. Although it is not illustrated, some differences across industries exist in their handling of energy inputs, most notably between electricity generation and other manufacturing industries. In addition, the agriculture and fossil-fuel industries contain equations that account for the presence of fixed inputs to production (land and fossil-fuel resources, respectively). Elasticity assumptions and the nesting structure of the production activities, which control the manner in which energy efficiency improvements can be achieved, are based on the EPPA model. Figure 2 shows how the capital-labor-energy composite good (KLE) is combined with materials inputs to produce final output. The assumption that this is done in fixed proportions ($s_{mat} = 0$) implies that businesses must either invest in more capital goods (i.e., new equipment) or hire more workers to achieve energy efficiency improvements. The elasticity $s_{KLE}$ controls these improvements by specifying how value added (the combination of capital and labor) can be substituted for energy. The last level in Figure 2 then determines how capital and labor can be substituted for each other and, in the nest of the five types of energy, specifies how one type of fuel can be used in place of another.

[6] The one exception is crude oil, which is modeled as a homogeneous good that is identical across all regions and has the same baseline price across all regions and modules (based on EIA world crude oil price forecasts).

**Figure 2. General Consumption, Trade, and Production Structures in ADAGE**




## Data

ADAGE combines economic and energy data to create a balanced social accounting matrix (SAM) for the year 2005 that provides a baseline characterization of the economy consistent with desired sectoral and regional aggregations.[7] Each SAM contains data on the value of output in each industry, payments for factors of production and intermediate input purchases by each industry, household income and consumption patterns, government purchases, investment, and trade flows. Economic data for the U.S. come from state-level data compiled by the Minnesota IMPLAN Group, while energy data come from the U.S. Department of Energy's Energy Information Administration (EIA).[8] Although IMPLAN data include the value of energy production and consumption in dollars, these data do not always agree with energy information collected directly from manufacturers and electric utilities by EIA. In addition, it is necessary to have physical quantities for energy consumption in the model to accurately estimate GHG emissions, which are not available from IMPLAN. Thus, EIA energy production and consumption, output, and economic growth forecasts for 2005 are used to adjust the year 2000 IMPLAN data. Procedures developed by Babiker and Rutherford (1997) and described in Rutherford and Paltsev (2000) are used to integrate relevant economic and energy data. Figure 3 shows the five U.S. regions used for this analysis. Each region contains the ten industries listed above and four representative households based on annual income: $0-$14,999; $15,000-$29,999; $30,000-$49,999; and $50,000 and above.

**Figure 3. ADAGE Regions Defined for this Analysis**


[7] In perfect-foresight models, agents will adjust their behavior in all time periods as soon as a policy is announced. Thus, if ADAGE began in the year 2000, policies under consideration today would unrealistically show effects in the model in the year 2000.

[8] Programs from Rutherford (2004) were used to organize and aggregate the IMPLAN data.

## Intertemporal Dynamics and Baseline Economic Growth

ADAGE incorporates four sources of economic growth: (1) technological change from improvements in energy efficiency, (2) growth in the available effective labor supply from population growth and changes in labor productivity, (3) increases in stocks of natural resources, and (4) capital accumulation. Historically, energy consumption per unit of output has declined over time because of improvements in production technologies and energy conservation. These changes in energy use per unit of output are modeled as exogenous autonomous energy efficiency improvements (AEEI), which alter the amount of energy needed to produce a given quantity of output. The AEEI are calibrated to replicate EIA forecasts for energy production by fuel type, energy prices, fuel consumption by industry, industrial output, and economic growth.[9]

Labor force and economic growth, electricity generation, changes in available natural resources, and resource prices are also based on EIA forecasts. Savings, which provide the basis for capital formation, are motivated through households' expectations about future needs for capital. Adjustment dynamics associated with formation of capital are controlled through the use of quadratic adjustment costs associated with installing new capital, which imply that real costs are experienced in order to build and install new capital equipment (Uzawa, 1969).

Prior to investigating policy scenarios, a baseline growth path is established for the model that incorporates economic growth and technology changes expected to occur in the absence of any new policy actions. Starting from the baseline SAM, EIA forecasts are incorporated to generate SAMs for each model year consistent with these forecasted values. Once this baseline is established, it is possible to run "counterfactual" policy experiments.

## GHG Emissions

ADAGE tracks fuel consumption in physical units (BTUs), based on EIA forecasts. Since $CO_2$ emissions from fuel use are tied directly to combustion of fossil fuels, the model is able to determine emissions levels in terms of millions of metric tons of carbon equivalent (MMTCE). Substitution options for, and the costs of, replacing energy inputs to production are controlled by the model's CES nesting structure and substitution elasticities. Households also have the ability to switch fuels, lower overall consumption, and improve energy efficiency to reduce emissions.

ADAGE has also endogenized emissions abatement costs associated with five non-$CO_2$ gases ($CH_4$, $N_2O$, HFCs, PFCs, and $SF_6$) based on the approach used in Hyman et al. (2002).[10] Unlike $CO_2$, these gases are not emitted in fixed proportions to energy consumption. Rather than relying on exogenous marginal abatement cost functions, which ignore interactions among the economic sectors, emissions of non-$CO_2$ gases are modeled directly as an input to production. This allows specification of abatement cost curves representing industry-specific costs associated with achieving reductions. Baseline emissions of these gases are matched to EPA forecasts through 2010 and extended along estimated growth paths from Hyman et al. (2002) thereafter.

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[9] Edmonds and Reilly (1985) first outlined this approach. See Babiker et al. (2001) for discussion of how this methodology was used in the EPPA model.

[10] Emissions of these gases are converted to carbon equivalents using their Intergovernmental Panel on Climate Change 100-year global warming potential values.

Regional shares of EPA's national emissions are based on regional output and consumption, assuming regions have equal emissions intensities for similar activities.

## Policy Scenarios

Effects of the GHG policies investigated in this paper were simulated using a permit trading program across all covered emissions sources in the appropriate model region(s). Programs are modeled as regional cap-and-trade policies; an approach that allows determination of a permit price that equalizes marginal abatement costs across covered sources and minimizes total costs of achieving emissions-reductions targets within the region. Costs associated with administering the trading programs and complying with any monitoring requirements are not incorporated.

The policies analyzed are presented in Table 1. In all scenarios, GHG emissions are capped at 1990 levels of $CO_2$ emissions, beginning in 2010.[11] Caps based on 1990 emissions have been chosen because of their continuing importance in policy debates, dating from when the Kyoto Protocol was first established with emissions caps referencing that year. In addition, these caps are similar to emission limits described in the NEG/ECP Climate Change Action Plan 2001.

## Table 1. Policy Scenarios

| Scenario | Description |
|---|---|
| 1. NE | Northeast cap on all GHG emissions (unilateral) |
| 2. NE_nonRES | Northeast cap on GHG emissions, except for residential emissions (including those from motor gasoline use in personal transportation) |
| 3. NE_Carbon | Northeast cap on $CO_2$ emissions alone |
| 4. NE_MW | Northeast and Midwest cap on all GHG emissions (with and without trading of permits between regions) |
| 5. US_Match | Cap on total U.S. GHG emissions matching level of reduction under the Northeast plus Midwest cap (Scenario 4) |

Scenario 1 examines the effects of unilaterally capping GHG emissions in the Northeast at 1990 levels starting in 2010, assuming that no offsets (i.e., purchasing of permits or emissions reduction activities) are allowed from any other regions. However, in practice, it appears unlikely that emissions-trading schemes will cover all GHG emission sources and all GHGs. Consequently, Scenario 2 investigates a possible alternative that assumes households will be exempted from requirements to purchase GHG permits and Scenario 3 restricts the cap-and-trade system to cover only $CO_2$ emissions (including residential $CO_2$ emissions). However, the Northeast region is still required to meet the same cap on total emissions as in Scenario 1.

Scenario 4 examines how policy costs and leakage of emissions across regions might change if a neighboring region (the Midwest) also capped their emissions – either with or without trading of

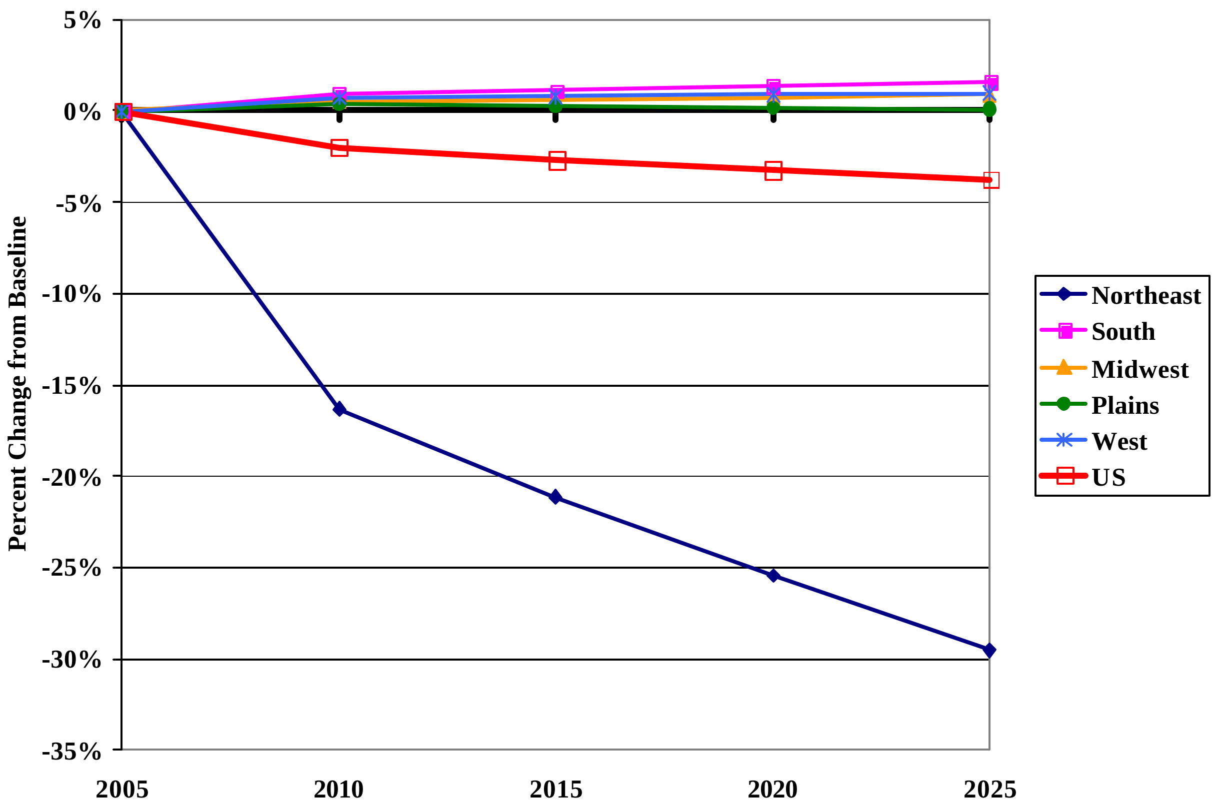
[11] $CO_2$ emissions from fuel consumption are used to set the cap, rather than emissions of all types of GHG, because better historical data exists for $CO_2$ emissions (based on fuel use). Note that the cap would be larger and less restrictive if all GHG emissions were considered when setting it.

permits with the Northeast region. Finally, Scenario 5 highlights the efficiency costs associated with restricting emissions reductions to the Northeastern and Midwest regions of the country by achieving the same quantity of reductions (in MMTCE) across the entire U.S. as occurred in Scenario 4 in the combined Northeast and Midwest regions.

## Simulation Results

Before comparing the relative cost-effectiveness of various methods for achieving emissions reductions, we examine the effects of a unilateral cap on Northeast GHG emissions (Scenario 1), the primary policy to which the other scenarios will be compared. Figure 4 provides the simulated changes in emissions for each U.S. region under Scenario 1. For the Northeast to reduce emissions to 1990 levels requires a 16% reduction relative to expected baseline emissions in 2010, increasing to a 30% reduction relative to baseline emissions by 2025. In the absence of similar actions by other regions of the country, total U.S. $CO_2$ emissions will fall by 2-4%.

**Figure 4. Percent Change in GHG Emissions under Northeast Cap (Scenario 1)**




Under this scenario, GHG-intensive production activities are expected to shift from the Northeast to the other regions of the United States, which do not have GHG limits. We find that, under this unilateral approach, there is fairly substantial leakage of emissions into other U.S. regions, as indicated in Table 2. In the absence of similar policies in other regions of the U.S., 21 to 27 percent of the reductions in the Northeast are offset by increases in emissions from these regions.[12]

**Table 2. GHG Emissions Changes and Leakage (Scenario 1)**

| Emissions Changes (MMTCE) | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|
| Northeast | 0.0 | -54.5 | -75.1 | -94.1 | -114.5 |
| South | 0.0 | 4.5 | 5.8 | 7.5 | 9.4 |
| Midwest | 0.0 | 2.8 | 3.4 | 4.3 | 5.4 |
| Plains | 0.0 | 1.4 | 1.1 | 0.8 | 0.4 |
| West | 0.0 | 2.8 | 3.4 | 4.1 | 4.7 |
| US | -0.1 | -43.1 | -61.4 | -77.3 | -94.5 |
| Leakage (%) | | 27% | 22% | 22% | 21% |

Table 3 presents general macroeconomic implications of Scenario 1 for various aspects of the economy in the Northeast and the country as a whole. The emissions limits are associated with GHG permit prices of $34 per MMTCE in 2010, rising to $82 in 2020. These permit prices cause a modest reduction in GDP in the region, and a somewhat smaller decline on overall consumption by households. Discrepancies between changes in output and consumption of goods and services in the region arise from the fact that, while the Northeast's economy is constrained by the emissions cap, people can still shift to purchases of goods produced in other parts of the United States with lower costs of production. The results show that GDP in regions outside of the Northeast has increased as a result of these shifts in production patterns.

**Table 3. Macroeconomic Effects on the Northeast Region (Scenario 1)**

| | Northeast | | U.S. | |
|---|---|---|---|---|
| **Variable** | **2010** | **2020** | **2010** | **2020** |
| Permit Price ($/MTCE) | $34 | $82 | | |
| GDP ($ million) | -$10,358 | -$30,282 | -$9,747 | -$29,063 |
| GDP (%) | -0.35% | -0.81% | -0.08% | -0.17% |
| Consumption (%) | -0.31% | -0.49% | -0.06% | -0.11% |
| Leisure Time (%) | 0.15% | 0.46% | 0.04% | 0.09% |
| Investment (%) | -1.40% | -1.94% | -0.21% | -0.28% |
| Employment - Jobs (%) | -0.09% | -0.28% | -0.02% | -0.06% |
| Wage Rate (%) | -0.53% | -1.07% | -0.11% | -0.23% |

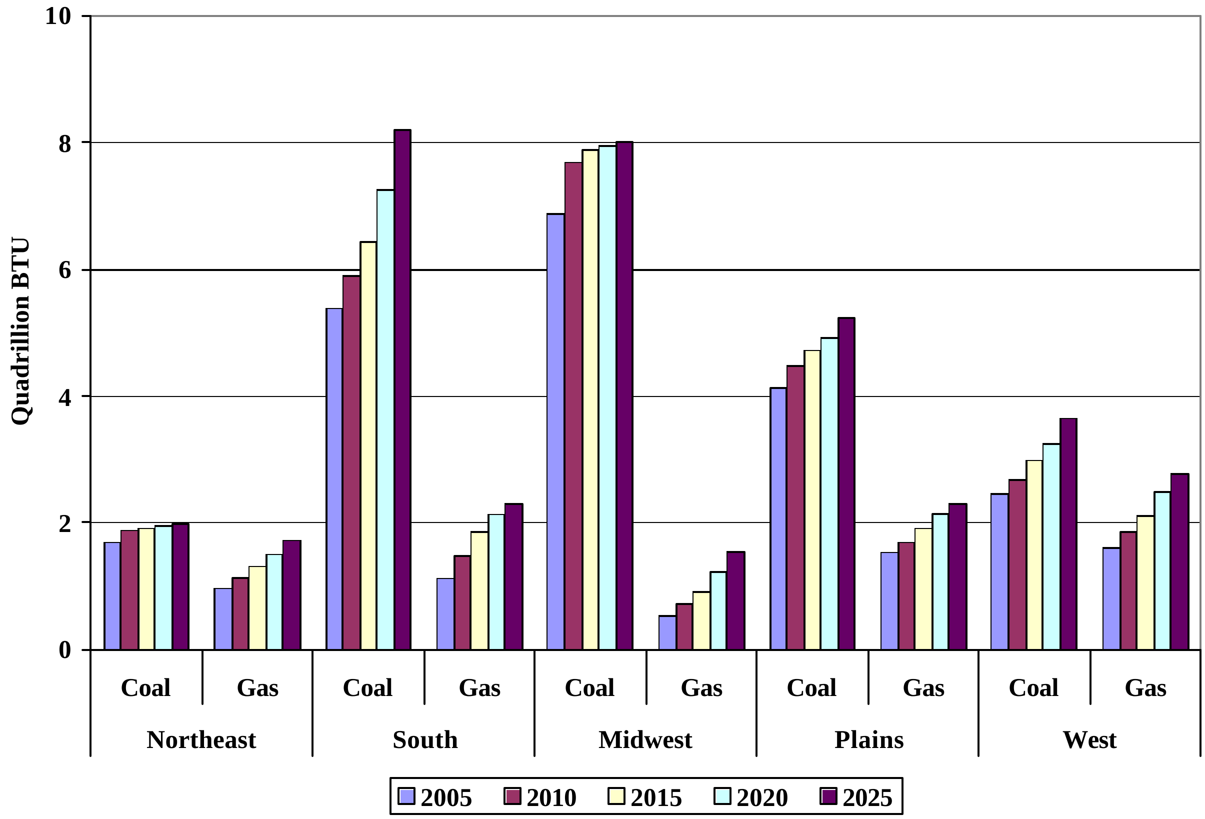
Across the economy, the industry providing the most cost-effective means for reducing a given amount of GHG emissions is usually electricity generation, which relies heavily on fossil fuels. GHG policies are generally expected to cause a shift from coal-fired generation to gas-fired

[12] Leakages are sensitive to assumptions on Armington trade elasticities, especially those related to electricity.

generation because gas utilities are more energy efficient and natural gas has less carbon per unit of heat output. This implies that, while areas of the United States with significant amounts of gas generation will have lower emissions initially, it will be relatively less expensive for regions with high shares of coal-fired utilities to lower their emissions.

Figure 5 illustrates the baseline consumption forecasts for natural gas and coal use by electric utilities. It indicates that the Northeast already relies fairly heavily on natural gas, compared to other parts of the country. This contributes to the overall costs of Scenario 1 observed in Table 3 and implies that, were the Northeast to engage in permit trading with other regions with more cost-effective options for lowering GHG emissions (i.e., coal-fired generation), their costs could be reduced. Baseline energy consumption by utilities also has implications for policy effects on electricity markets, trade flows, and prices.

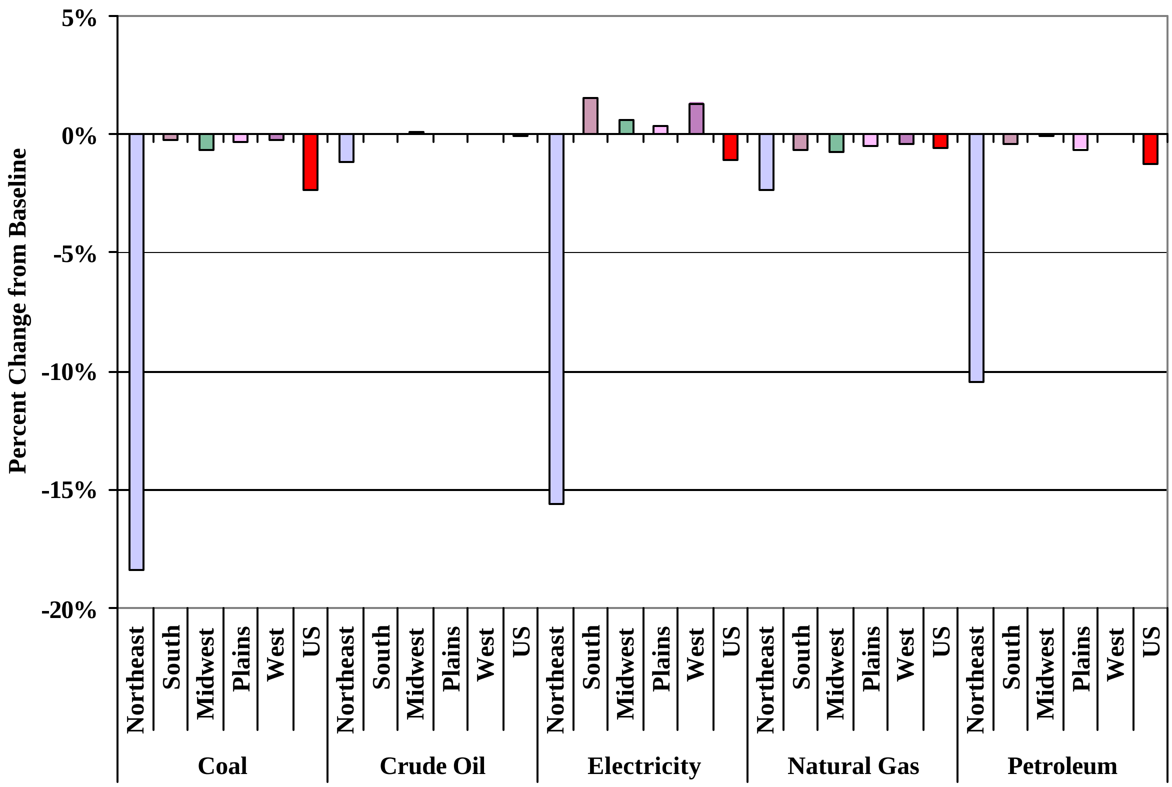
**Figure 5. Coal and Natural Gas Use in Electricity Generation (Baseline)**




Electricity prices in the Northeast rise by 10-25% relative to baseline conditions over the period from 2010 to 2025 as the result of increased costs of generation due to higher fuel input costs and additional use of capital and labor to improve energy efficiency. Electricity prices in other regions are less affected in general since it has been assumed their utilities do not need to purchase permits. Also, declines in national demand for coal and natural gas depress fuel prices, reducing the cost of electricity production in other regions.

As shown in Figure 6, U.S. electricity output declines in 2015 compared to the baseline. However, this is solely the result of the drop in the Northeast. All four other U.S. regions actually generate more electricity, both to sell to the Northeast and to accommodate shifts in industrial output within their borders. Coal production, on the other hand, falls across all regions with the decline in demand from the Northeast since the majority of coal consumption occurs in electricity generation, which has fallen in total.

**Figure 6. Changes in Output of Energy Industries in 2015 (Scenario 1)**




Other industries across the nation are also affected by the Northeast policy, as shown in Figure 7. Agriculture, which is associated with emissions of methane and nitrous oxides, tends to decline in the Northeast, while other areas expand their production. Similarly, increases in costs of producing energy-intensive goods in the Northeast leads to lower output, which is offset by increases in the remaining regions. These types of shifts in manufacturing, along with changes in electricity generation, help explain the increases in GHG emissions in other regions of the U.S. Services, on the other hand, are relatively unaffected outside of the Northeast. Given the relatively low energy intensity of producing services, this industry does not experience a significant increase in comparative advantage relative to firms in the Northeast.

A strategy for addressing climate change mitigation that covers all GHG emissions from all sources (and regions) will be the most cost-effective method of achieving reductions. Assuming the GHG policy is implemented as a unilateral strategy within the Northeast region, the cap-and-trade system employed in Scenario 1, which covers all GHG emissions from all sources, is the most cost-effective method of reaching emissions targets. Less comprehensive trading systems will have higher costs to achieve the same goal, while broadening the geographic area from which emission reductions can be obtained may significantly lower costs.

**Figure 7. Changes in Output of Other Industries in 2015 (Scenario 1)**

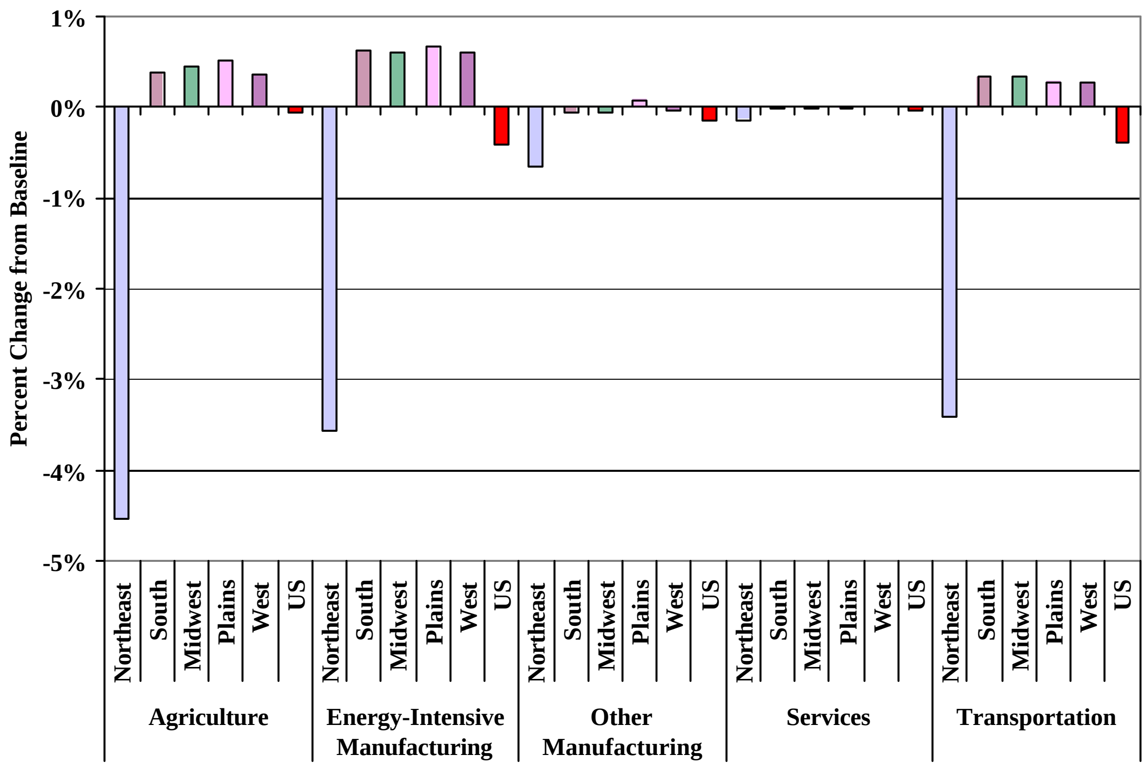
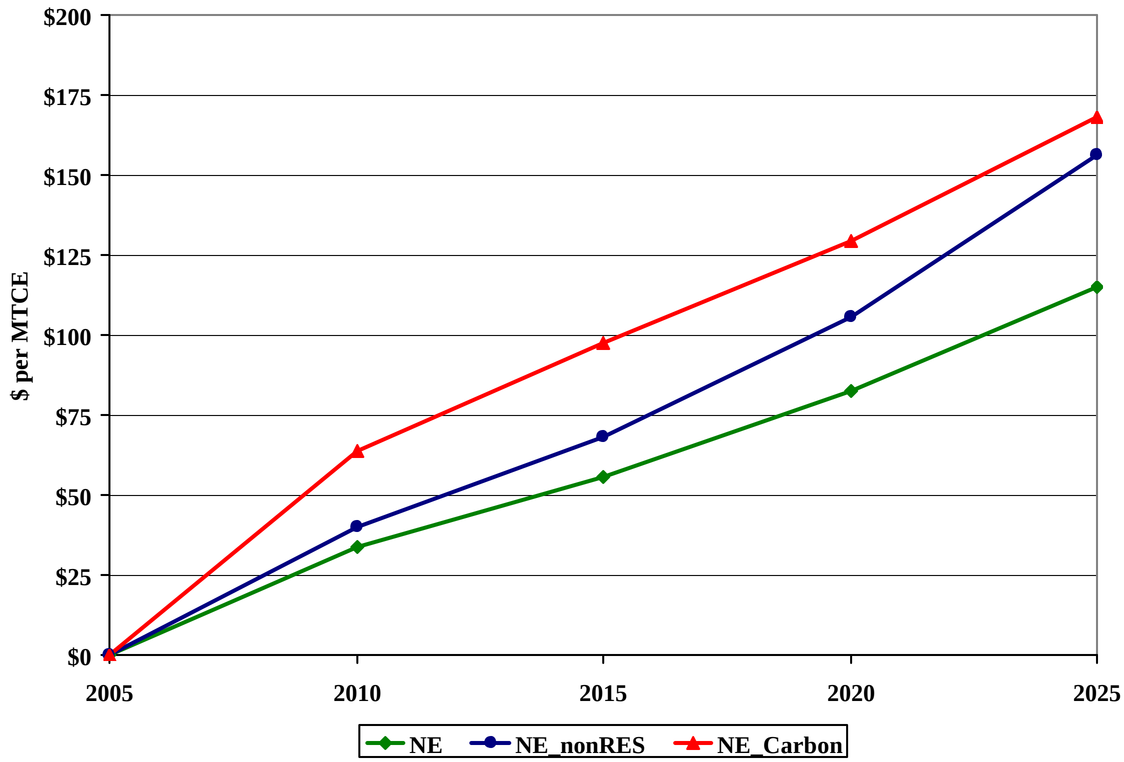


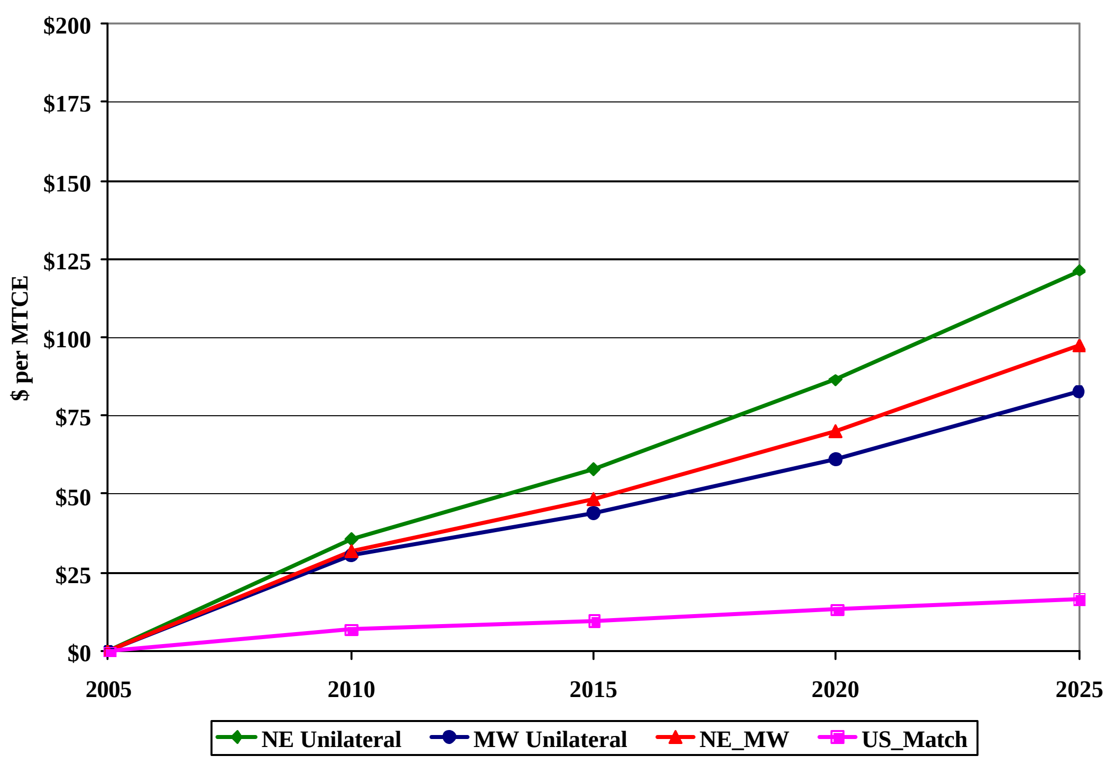

Figure 8 compares efficiency costs across the unilateral Northeast region scenarios from Table 1 (Scenarios 1-3) by examining their GHG permit prices (all three schemes provide the same level of emissions reductions). A unilateral cap on all GHG emissions in the Northeast (Scenario 1 – "NE") gives permit prices of $34 per metric ton of carbon equivalent in 2010. Scenario 2 ("NE_nonRES"), which excludes residential emissions from the trading program, raises permit prices by 20% to 35% relative to the case where all emission sources are covered. Scenario 3 ("NE_Carbon"), which only includes $CO_2$ in the trading program, increases permit prices by between 45 to 85 percent.

Figure 9 illustrates how expanding the regional coverage of GHG policies reduces costs by providing additional low-cost mitigation options. Scenario 4 ("NE_MW") looks at the situation in which both the Northeast and Midwest regions lower their emissions to 1990 levels, either through unilateral caps or a joint trading program. Without trading, the regions face permit prices shown by "NE Unilateral" and "MW Unilateral", respectively. Under a joint cap, all parties in the combined Northeast/Midwest region would pay the "NE_MW" permit prices. GDP costs to the Northeast are 15 to 20 percent lower under the "NE_MW" joint trading scenario than in the unilateral Scenario 1 policy. Finally, Scenario 5 ("US_Match") assumes that the absolute emission reduction achieved under Scenario 4 in the Northeast and Midwest is now spread across the entire U.S. The significantly lower permit price in Scenario 5 illustrates how continued expansion of the geographic coverage would further reduce the marginal cost of achieving GHG targets.

## Figure 8. GHG Permit Prices across Scenarios 1, 2, and 3




## Figure 9. GHG Permit Prices Under Expanded Regional Coverage



Along with achieving emissions reductions at the lowest possible cost, expanded coverage of a GHG policy can greatly reduce leakage of emissions into surrounding regions.[13] For 2010, emission leakage is reduced from 27% to 6% when coverage is expanded from Northeast only to both Northeast and Midwest. In part, this occurs because the Midwest has a large share of coal-fired electricity generation that, under a unilateral Northeast cap, expanded production to supply electricity to the Northeast. Under a more comprehensive policy, this is unlikely to occur since coal consumption in the Midwest would be included in the new cap.

## Distributional Effects on Households

Implications of GHG policies for different household categories (defined by annual income) will depend on consumption patterns. In the Northeast baseline, households spend 4% of their budget on energy goods in 2005, declining to around 3% by 2025 (energy expenditures are expected to grow more slowly than overall consumption expenditures). However, the share of income devoted to energy goods tends to decline as income rises, which has the potential to make GHG policies regressive. Table 4 presents ratios comparing consumption of different goods and services as a share of income by household income category to the average across all households in the Northeast. These show that in almost every case, the relative share of expenditures on energy goods declines as income increases. For example, households in the Northeast spend an average of about 1% of their total budget on electricity. Thus, Table 4 implies that households making less than $15,000 per year spend 1.39% of their budget on electricity, while those above $50,000 spend about 0.86% of their budget. Similarly, the average household spends

## Table 4. Consumption as a Share of Income Relative to the Average (Baseline)

| | All House-holds | Income 0-15K | Income 15-29K | Income 29-50K | Income 50K+ |
|---|---|---|---|---|---|
| Electricity | 1.00 | 1.39 | 1.08 | 0.89 | 0.86 |
| Natural Gas | 1.00 | 1.20 | 1.02 | 0.94 | 0.95 |
| Petroleum | 1.00 | 1.01 | 1.08 | 0.98 | 0.96 |
| Agricultural Produce | 1.00 | 1.17 | 1.10 | 0.95 | 0.89 |
| Energy-Intensive Goods | 1.00 | 1.31 | 1.11 | 0.92 | 0.83 |
| Other Manufactured Goods | 1.00 | 0.87 | 0.98 | 1.02 | 1.06 |
| Services | 1.00 | 0.99 | 0.99 | 1.01 | 1.01 |
| Transportation | 1.00 | 0.91 | 0.88 | 1.02 | 1.14 |

approximately 6.3% of their budget on energy-intensive goods, while high-income households spend around 5.2% (6.3% times 0.83). In addition to energy goods, lower-income households spend more on agricultural products and energy-intensive goods (many foods appear in the

[13] There will be no domestic leakage from a national policy, by definition. However, international leakage is likely and may increase as domestic policies become more comprehensive.

"Energy-Intensive Goods" category in the current sectoral aggregation because EIA classifies food processing as an energy-intensive industry).

These spending patterns contribute to the changes in welfare shown in Table 5 for Scenario 1. Households with the lowest annual incomes experience the largest proportionate declines in welfare, although there are relatively small differences up to $50,000 per year. High-income consumers with the lowest dependence on energy goods have the lowest proportionate welfare losses associated with GHG emission reductions in this scenario.

**Table 5. Welfare Results for Households (Scenario 1)**

| | Income 0-15K | Income 15-29K | Income 29-50K | Income 50K+ |
|---|---|---|---|---|
| **Northeast** | -0.37% | -0.35% | -0.32% | -0.17% |
| **South** | -0.02% | -0.01% | 0.00% | -0.01% |
| **Midwest** | 0.00% | 0.02% | 0.04% | 0.03% |
| **Plains** | -0.04% | -0.06% | -0.09% | -0.15% |
| **West** | -0.03% | -0.02% | -0.01% | -0.02% |
| **US** | -0.09% | -0.08% | -0.08% | -0.06% |

## Conclusions

There has been growing interest in developing climate policy at the subnational level in recent years. Many U.S. states have already approved legislation or instituted executive orders aimed at reducing GHG emissions, and many other states are considering similar actions. States potentially have an important role in development and implementation of climate policy, but face barriers that prevent their policies from perfectly substituting for a comprehensive national or international approach. Subnational climate change mitigation policies may prove to be a practical approach to begin addressing global warming, but may also introduce inefficiencies as states institute different and potentially incompatible requirements for climate change mitigation. In addition, constraining opportunities for reducing emissions by limiting the sources, regions, or GHGs subject to restrictions can significantly increase total costs of hitting a given mitigation target.

To examine the potential magnitude of inefficiencies associated with mitigating a given level of GHG emissions with restrictions on geographic area, sources, and GHG gases included in a cap and trade program, we use a region-specific general equilibrium model to analyze scenarios similar to those that may emerge from current policy debates. Our policy simulations show that spreading emissions reductions across as many sources as possible will substantially lower mitigation costs. The results also reveal the potential for fairly substantial interregional shifting of GHG-intensive activities (leakage); for example, 20%-25% of emissions reductions in the Northeast could be offset by increases in uncontrolled regions under a unilateral regional approach. We also show that consideration should be given to the potentially regressive nature of GHG policies.

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# IMPLAN Based Impact Modeling for Commercial Fisheries on Florida's East Coast: Alternative Approaches and Recommendations

**by David Mulkey, Tom Stevens, and Alan W. Hodges**

## Introduction

This paper reports the results of a study to evaluate alternative approaches to developing an input-output modeling capability that will allow the National Marine Fisheries Service to complete economic impact studies associated with specific fishery regulatory changes.[1] The study is based on the potential use of the IMPLAN (IMpact Analysis for PLANing) Professional ® software modeling package and associated databases.[2] Specific objectives include:

a. describing IMPLAN Professional (IMPLAN) software and databases with regard to existing fishery related sectors,

b. evaluating the existing IMPLAN sectoring scheme with respect to the geographic distribution of landings on Florida's east coast, the harvesting technology utilized, and product flows between harvesting, processing, wholesale and retail sectors.,

c. recommending adjustments to standard IMPLAN models with respect to the number and nature of fishing sectors and the need for state and/or sub-state models, data requirements to support adjustments, and an evaluation of existing data, and procedures for implementing the recommended approach.

Following sections provide a descriptive overview of the fishery along Florida's east coast followed by an overview of the IMPLAN regional modeling system and specific applications to estimating fishery impacts. A final section presents conclusions and recommendations.

### The Florida East Coast Fishery: An Overview

To develop guidelines for modifying standard IMPLAN models to more accurately estimate economic impacts of changes in Florida's east-coast commercial fishing industry, it is important to review the industry, how fishing technology varies among different segments, and how the industry is geographically distributed within the State. Industry sectors may be defined based on species harvested and/or type of fishing gear used. Further, any analysis and definition of sectors may treat the entire east coast as one economic area or focus on sub-regions along the coast. In either case the specification of sectors and/or regions should reflect the nature of the fishing industry and the realities of defining those sectors within the context of functional economic regions.

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[1] Work on the project was funded by a grant from the National Marine Fisheries Services, University of Florida Project 03060952.

[2] MIG, Inc., IMPLAN Professional 2.0: User's Guide, Version 2.0. (http://www.implan.com).

Saltwater commercial landings along Florida's east coast have declined since 1984, when they peaked at 89.2 million pounds. Landings for 2002 came in at a historical low of 21.6 million pounds. The value of 2002 landings is estimated at $33.8 million, which is the lowest since 1979. The average ex-vessel price for east-coast landings has been relatively stable since 1999, fluctuating in a narrow range around $1.60 per pound on an annual average basis.[3]

Geographically, there is considerable variation in the volume and value of landings along Florida's east coast (Figure 1). For the five years from 1998 to 2002, the total value of landings ranged from a high of $71.2 million for Brevard County, to a low of $93.1 thousand for Flagler County. The order of Counties along the horizontal axis in Figure 1 is from north to south along Florida's east coast, with Nassau County being the northern-most and Miami-Dade being southern-most. Three sub-regions of fishing activity are suggested by this graphic, with Flagler county being a dividing point between northern and central sub-regions, and central and southern sub-regions being divided at the border between St. Lucie and Martin counties. These three regions would then consist of North: Nassau, Duval and St. Johns; Central: Flagler, Volusia, Brevard, Indian River, St. Lucie; and South: Martin, Palm Beach, Broward and Miami-Dade. For later reference, these three regions correspond to Department of Commerce, Bureau of Economic Analysis (BEA) "Economic Areas". A map showing these areas is provided in Figure 2.

There is also geographic variation of targeted species groups up and down the coast. Revenues from shrimp landings dominate the northern and central sub-regions of the east coast (Figure 3). Landings of invertebrates (other than shrimp) and fin-fish are greater in the central division of the coast between Volusia and Indian River Counties. Miami-Dade County and the southern end of the study area has the highest diversity of catch among the four groups of species.

In Figure 4, the 5-year total value of different fin-fish species landings on the east coast is shown in decreasing order of magnitude. King Mackerel is the most economically important individual species for this coast with a cumulative value exceeding $18 million between 1998 and 2002. With landings valued at nearly $17 million, Swordfish come in as a close second. Spanish Mackerel and Black Mullet had the third and forth largest cumulative values, each exceeding 4 million over the period. With a combined value of nearly $107 million, food shrimp dominate all other forms of invertebrates harvested on Florida's east coast (Figure 5). Other significant invertebrate species include Blue Crab, with a landings value approaching $19 million between 1998 and 2002, followed by Spiny lobster and Hard Clams, each with landing values exceeding $10 million for the period. (Figure 5).

While fishery regulation is often designed for particular species, modeling the economic impacts of regulating the harvesting of individual species will be highly dependent on the particular technology involved. The cumulative share of landing values harvested with the ten most important gear types is shown in Figure 6. The most important gear type in terms of cumulative

[3] Data on volume and ex-vessel value of commercial fish landings by species, gear type and county were obtained from Steve Brown with the Florida Marine Research Institute, of the Florida Fish and Wildlife Conservation Commission, 100 8th Avenue SE, St. Petersburg, Florida 33701 (727) 896-8626, steve.brown@fwc.state.fl.us. Comparable data are also available on the Internet from the National Marine Fisheries Service at: http://www.st.nmfs.gov/st1/commercial/index.html

harvest value are Bottom Trawls, which are use for catching shrimp. Hand and long lines are the second and forth most important gear type and are used to harvest various species of fin fish. Pots and traps are the third and sixth most important gear type, in their use for harvesting crab and lobster respectively. As suggested by the figure, some gear-types are highly correlated to targeted species. For example, hand lines and troll lines are the predominate gear types used for King Mackerel. For the next most important fin-fish species, Swordfish, long-lines with hooks are used to catch the majority of value. As already implied, the most economical important marine species, shrimp, are caught primarily with bottom trawls.

The geographic distribution of all stages of the seafood industry will be important to accurately modeling the impacts of regulatory changes. The percentage distribution of seafood harvesters and handlers across east-coast counties of Florida is presented in Figure 7. The regional pattern is similar to that for the value of landings noted earlier, but with a larger concentration of dealers, brokers, processors and distributors in the southern most counties. The latter is likely explained by higher levels of import-export activities due to the location of port facilities in the area and the frequency of use by Latin American shippers.

**Figure 1. Florida East Coast Fishery: Sum of Landings and Value by County, for five years between 1998 – 2002**

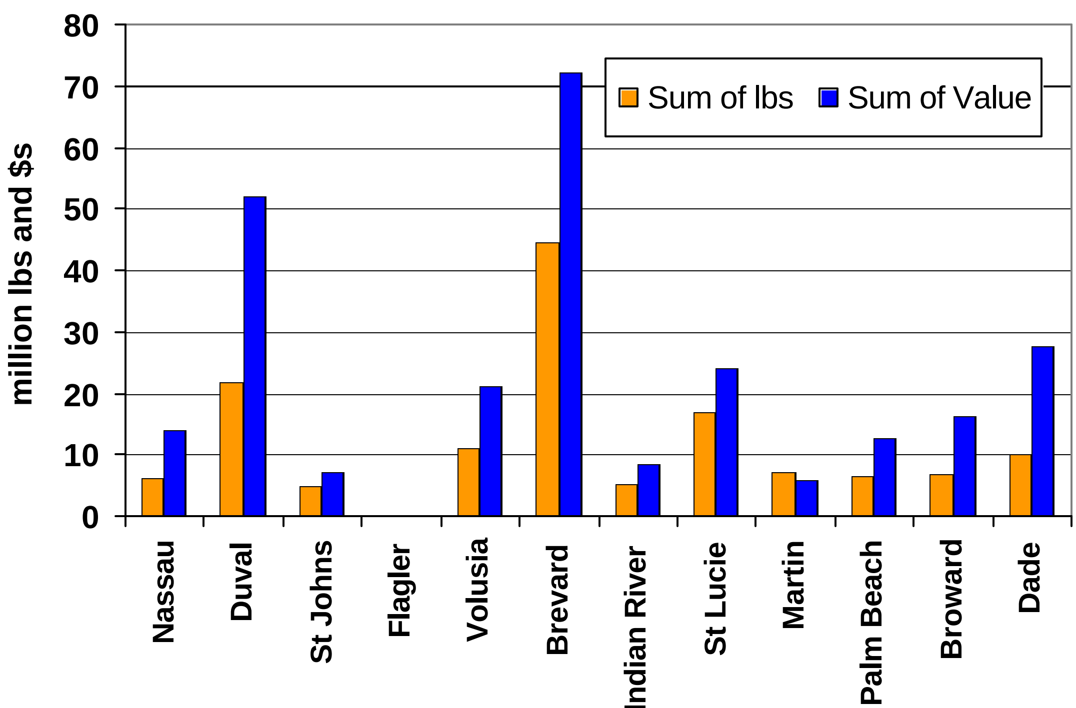


**Figure 2. Bureau of Economic Analysis Economic Areas for the East Coast of Florida .**

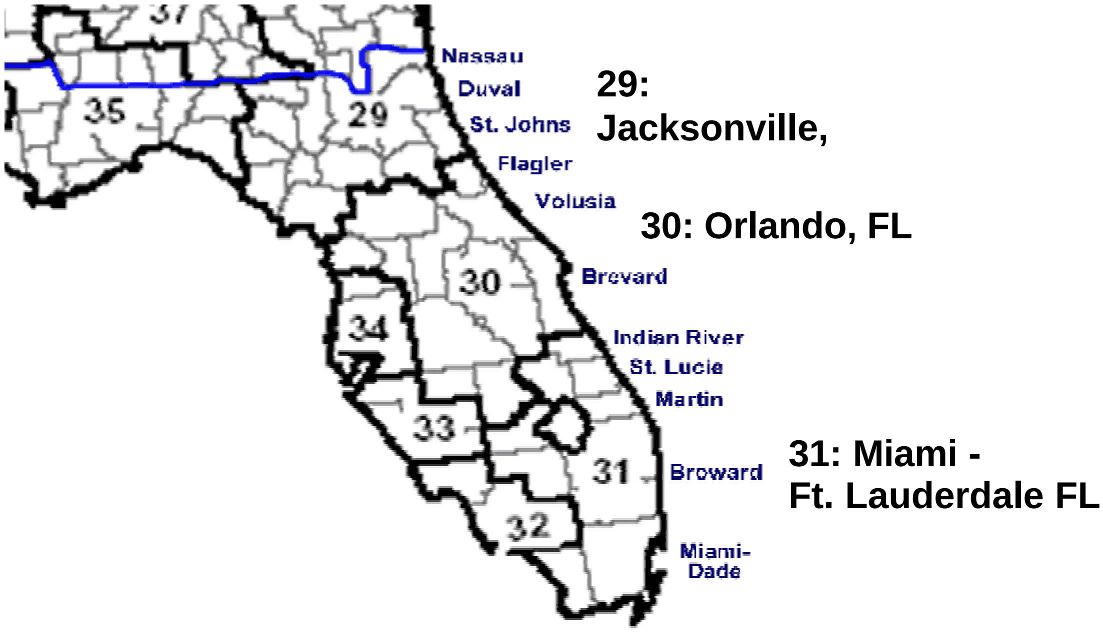



**Figure 3. Florida East Coast Fishery: Sum of Value of Landings by County and Species Group for 5 years between 1998 – 2002.**

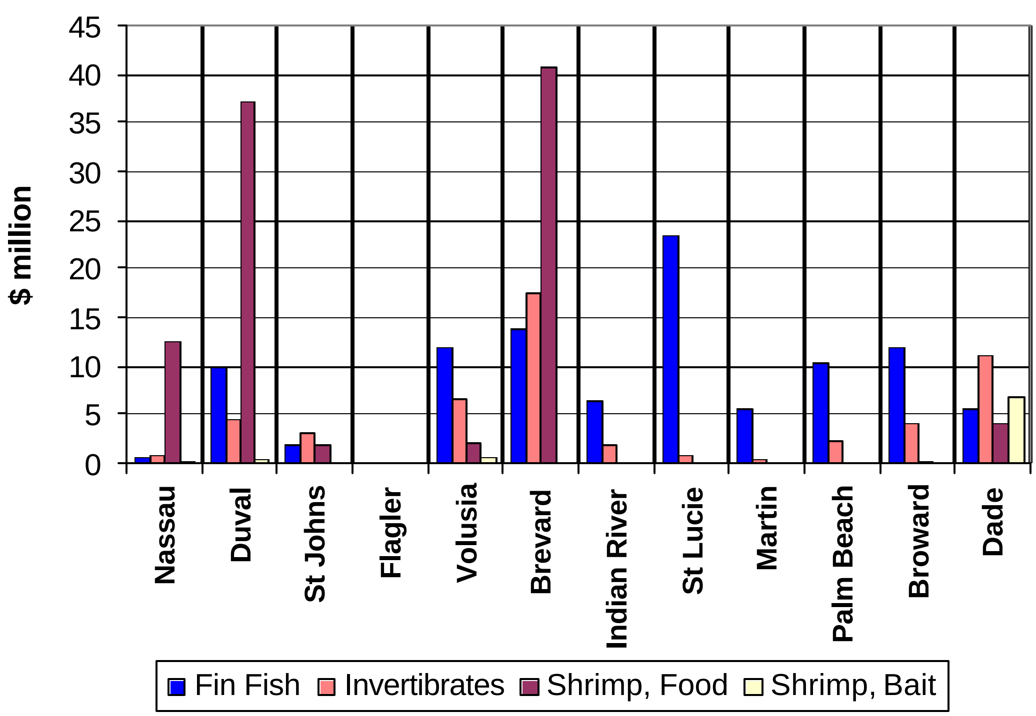


**Figure 4. Florida East Coast Fishery: Sum of Value of Fin Fish Species with Total Landings Values Exceeding $1 Million for 1998 – 2002.**

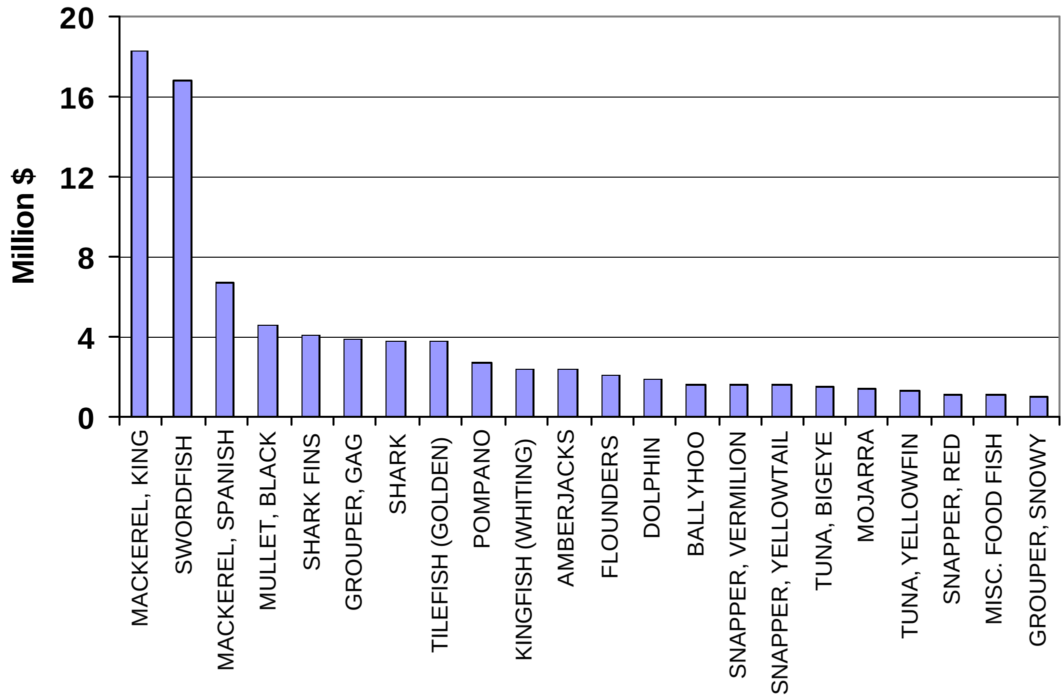
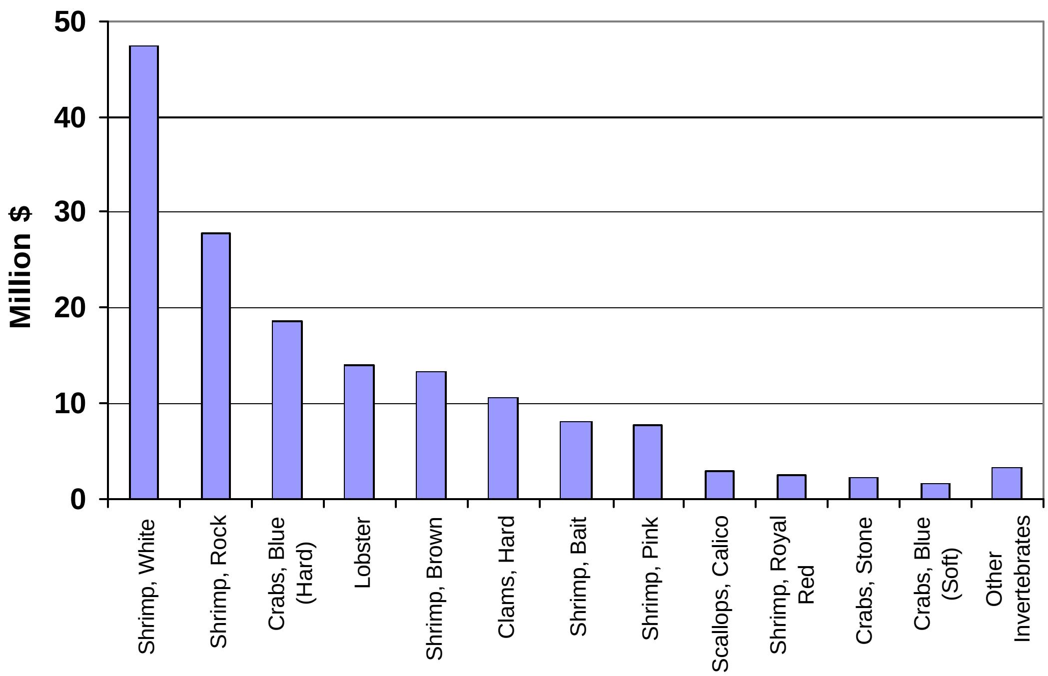
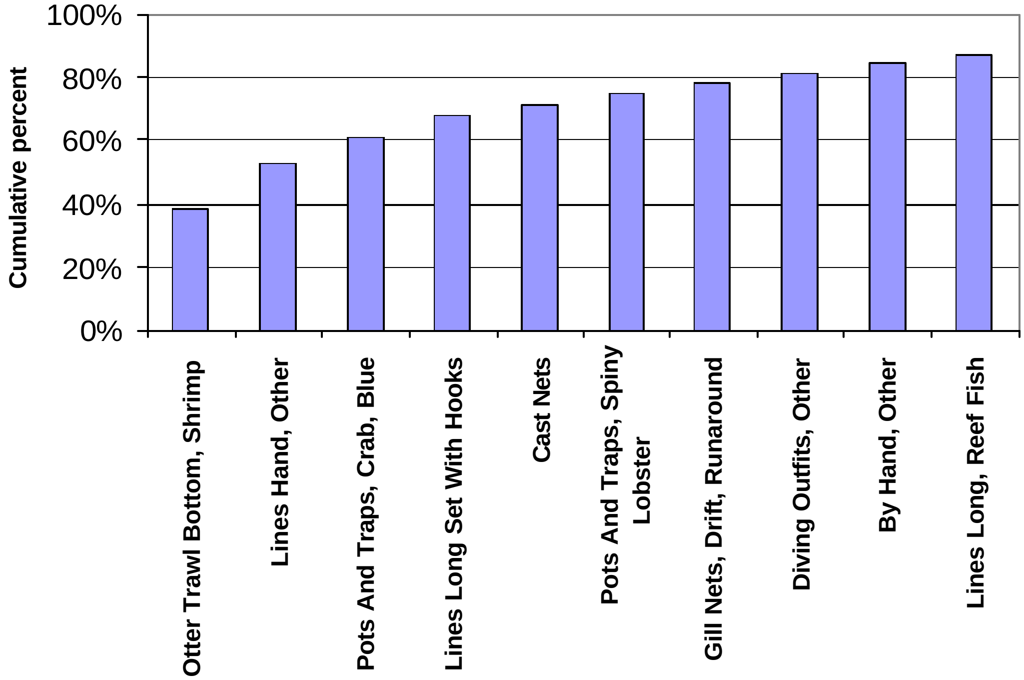



**Figure 5. Florida East Coast Fishery: Sum of Value of Shrimp and other Invertebrate**



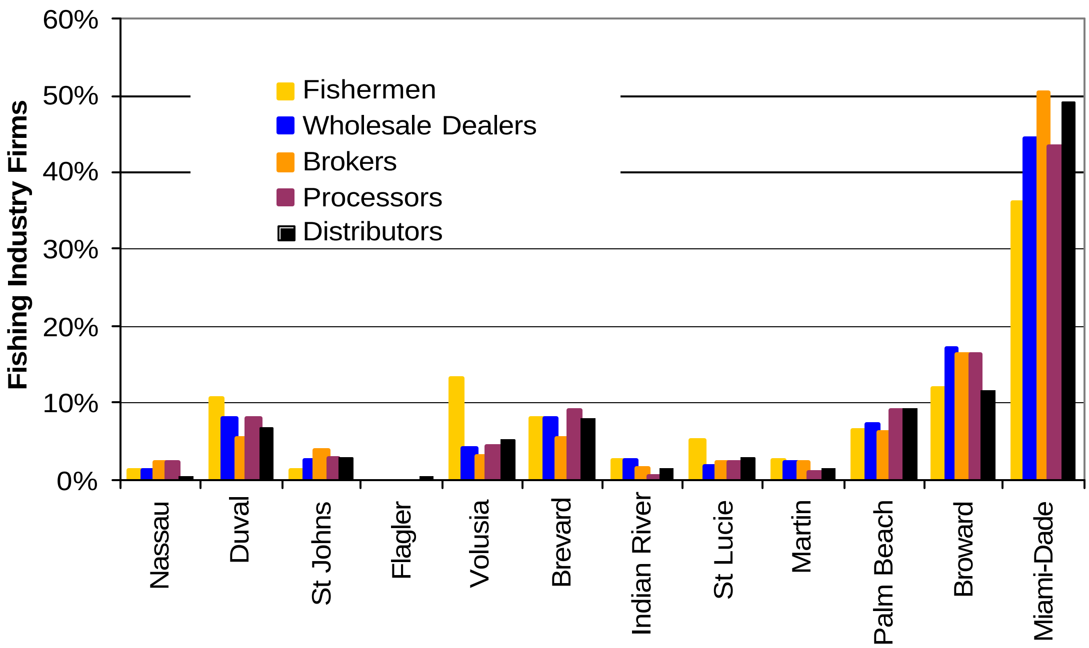

**Species Harvested, 1998 – 2002**

**Figure 6. Florida East Coast Fishery: Cumulative Share of Total Value of Landings by**




**Top Ten Gear-types for 5 years between 1998 – 2002**

**Figure 7. Percentage Distribution of Seafood Harvesters and Handlers along Florida's East Coast, 2003**




Southeast Fisheries Science Center, www.sefsc.noaa.gov/seafooddealers.jsp

## State and Federal Fisheries Data Programs

Considerable data collection programs have been developed to help monitor and evaluate and manage the fisheries around Florida and the Nation as a whole. Over time, cooperative relationships have been established between the National Marine Fisheries Services and the Florida Fish and Wildlife Commission (along with other states) so that fishery data collection and organization is more consistent and comprehensive. Table 1 summarizes the programs and types of data collection currently taking place for the east coast of Florida.

The Fisheries Logbook System requires fishermen to complete reports that are specific to several different types of fisheries, including: Pelagic longline, Gulf reef, South Atlantic Snapper-Grouper, Coastal Shark, and King and Spanish Mackerel fisheries. This program is implemented by the Southeast Fisheries Science Center (SEFSC). A Pelagic longline report is completed for each longline baited and set in the water (multiple longlines may be set during a single trip for this type of fishery). The logbook forms for the other fisheries summarize a single trip instead of individual sets. Data collected include: Vessel ID, date and length of trip, fishing location, gear type and quantity, and catch by species, weight and value. Cost and effort data fields have recently been added to this report and are discussed below.

To assess the age and size distribution of various marine fish species, the SEFSC also conducts a Trip Interview Program. Trip interviews are conducted on shore (at dockside or dealer locations) by trained surveyors. These surveyors also observe the composition of catch and take biological samples of fish caught. Biological samples are used to determine the age, reproductive status, and genetic characteristics of the catch. These first-hand interviews are also used to confirm logbook and trip ticket data (discussed below).

Commercial fishing vessels are counted and identified for regulatory purposes (in conjunction with the U.S. Coast Guard) through the NMFS's Vessel Operating Unit program (Table 1). This program only counts vessels that are registered with the US Coast Guard, which only includes vessels weighing 5 net tons or more.

NMFS has recently implemented a program to collect data on costs and returns of commercial fishing operations for the snapper/grouper & mackerel fisheries. Collected data include both fixed (annual) and variable (per trip) costs. Selected fishing vessel captains receive modified logbooks to record trip costs, in addition to annual (fixed) cost reporting forms. This program is being conducted in collaboration with the Atlantic Coastal Cooperative Statistics Program to help insure the consistency and integrity of collected data.

A collaborative data collection program between individual states and NMFS to track fishery harvests is called the Accumulated Landings System. Marine Fishery Trip Tickets are completed by seafood dealers and brokers. The species, weight, and value of fish purchased from fishermen are recorded in these reports on a per-trip basis. The length of time, area and depth fished, as well as gear-types used and type of fishing operation are also noted in these reports. These data are often reviewed by local NMFS port agents to reflect more accurate "ground truthed" data. Thus, the landings for an individual state as reported via local Trip Tickets may not match the adjusted Accumulated Landings System data.

The Atlantic States Marine Fishery Commission is currently developing a comprehensive data collection system, known as the Atlantic Coastal Cooperative Statistics Program. Part of this program will focus on market and vessel-level cost data. These data will allow for more effective state and federal management efforts.

As previously mentioned, the Florida Fish and Wildlife Commission (FWC) is responsible for conducting the Trip Ticket program. Although these data detail the landings for individual trips by fishermen, the State carefully maintains the confidentiality of these data by only releasing summaries of fishery landings by month, species, and location. These data allow the FWC and the NMFS to monitor fishery harvest and adjust regulations as needed to maintain healthy marine populations.

The SEFSC also maintains extensive lists of U.S. seafood dealers, brokers, processors, distributors and fishermen. These lists are made available to the public through their website at http://www.sefsc.noaa.gov/seafooddealers.jsp. All names and associated data are obtained from public sources or voluntarily provided to the agency. Data include business and contact names, address, phone number, email address, product types and species handled, also the types of processing carried out are listed.

**Cost and Effort Data Requirements.**

Data on the costs of production (harvesting), processing and distribution of goods or services are necessary to accurately conduct economic impact analyses. The cost of harvesting a specific marine species is determined to a substantial degree by the technology (types of vessels and fishing gear ) used for this purpose. An analysis of the value of fishery landings by gear-type for the east-coast of Florida indicates that the following seven gear types are used in harvesting

**Table 1. Data and Information Sources Relevant to Fisheries Data and Socio-economic studies of the Fishery Industry.**

| Agency | Title of Data | Location/Contact/Completed by | Type of Data |
|---|---|---|---|
| National Marine Fisheries Service (NMFS),<br>Fisheries Statistics & Economics Division, &<br>Southeast Fisheries Science<br>Center (SEFSC) | Fisheries Logbook System (FLS) | Written report forms completed by fishermen http://www.sefsc.noaa.gov/<br>http://www.sefsc.noaa.gov/fls.jsp | Catch & effort data by species, per trip or set. Includes species caught, by-catch, area of catch, type & quantity of gear, departure & return dates, landing & dealer location, fishing time & man hours. |
| | Trip Interview Program (TIP) | Collected at landing site or dealer location by port agents on South Atlantic & Gulf of Mexico coasts. http://www.sefsc.noaa.gov/tip.jsp | Size, weight & age data of catch by species determined through biological samples & personal interviews with fishermen. Catch & effort data collected include type & quantity of gear, crew size, & days fishing & trip length |
| | Vessel Operating Units (VOU) | Based on U.S. Coast Guard vessel data base http://www.sefsc.noaa.gov/vou.jsp | Characteristics and ownership data for commercial fishing vessels greater than five net tons |
| | Social & Economic Aspects of Fishery Management, Cost & Earnings Data Collection Program for South Atlantic Fisheries | Written report forms completed by fishermen (initially only snapper/grouper & mackerel fisheries)<br>http://www.safmc.net http://www.safmc.net/socio/fmpro?-db=content&-format=default.html&-view | Voluntary random sampling for annual fixed costs & trip costs, including variable costs for a commercial fishing vessel's most recent trip, also sociological information through annual surveys of owner/captain/crew. |
| | Accumulated Landings System (ALS) | Reported by dealers/brokers to the Florida Fish & Wildlife Comm., usually on written Trip Ticket forms. See FMRI below http://www.st.nmfs.gov/st1/commercial/<br>http://199.242.233.242/sefsc/commercialprograms.jsp.htm | Quantity & value of domestic commercial seafood landings by species, gear-type, area, year/month as sold to dealers or brokers. NMFS coops with SE states to collect & process data. Maintained by SEFSC |
| | Seafood Dealer Lists | Lists of firms in seafood industry (National)<br>http://www.sefsc.noaa.gov/seafooddealers.jsp | Business & contact name, address, phone, email, product types and species handled, types of processing carried out. |
| | | | |
| Florida Fish & Wildlife Commission, Marine Research Institute | Marine Fisheries Trip Ticket system | Reported by dealers or brokers to the Florida Wildlife Commission, & is then transmitted to the NMFS Accumulated Landings System. http://www.floridamarine.org<br>http://www.floridamarine.org/features/view_article.asp?id=19224 | Includes ID of harvester, purchasing dealer, date of the transaction, county landed, time fished, & pounds of each species landed. Used to generate Status & Trends Reports & support NMFS ALS. |

nearly 90 percent of the value of these landings: bottom otter trawl, hand lines, pots and traps, long lines, cast nets, drift or runaround gill nets, and diving (Figure 9). The cost and effort data that have been collected and published for 2002 do not include observations for trawls, or pots and traps. This is because the 2002 collection effort was focused on the snapper/grouper & mackerel fisheries and not crustaceans or shell fish.

To date, very little data has been discovered that specifically describe the technology and costs of processing and distributing seafood within the state of Florida. As with harvesting, this type of data could be used to improve the accuracy of estimated economic impacts from changing fishery regulations as they relate to the value-adding sectors of the seafood market channel. Also, to estimate impacts of regulatory changes for particular sub-regions or communities within the State, information on the flows of seafood related products and services within the State will be needed. As with harvesting, the standard IMPLAN model has only one sector for seafood processing. There is no specifically designated IMPLAN sector to represent seafood dealing, importing, exporting, or distribution.

## The IMPLAN Regional Modeling System

**An Overview:** Regional economic models constructed using IMPLAN are input-output (I/O) models and embody all the standard I/O assumptions such as constant returns to scale, no supply constraints, a fixed commodity input structure, homogenous sector outputs and the assumption that an industry uses the same technology to produce all outputs. Input-output models can then be used to assess the total effect on the economy resulting from direct changes in any one sector or combination of sectors. Models are demand driven and ideally suited to estimate the direct, indirect and induced effects of changes in the final demand for the product of any given sector. Expressed mathematically in matrix notation:

$$X - AX = Y$$

Where: X is a vector of outputs for each sector (1 though n) of the economy

Y is a vector of final demands for the product of each sector (1 though n) in the economy, and

A is a matrix of technical coefficients where each element $a_{ij}$ reflects the purchase by a column sector j from each row sector i per dollar of sector j's output.

The equation is then solved for the output (employment and income) impacts, given a change in final demand:

$$X = (I - A)^{-1} Y ,$$

where X, A, and Y are defined as before, and I is an identity matrix. Each element of the inverse matrix $a^{-1}_{ij}$ reflects the total output requirement from sector i per dollar of delivery to final demand by sector j. For a given sector j, summing across all i represents the multiplier effect of a final demand change in sector j. Effects captured include:

<u>Direct effects</u>: sales, income and employment occurring directly in the sector in question, in this case the harvesting of fish, and the output of seafood dealers and processors.

Indirect effects: sales, income and employment in those businesses linked to the sector in question through input purchases, in this case purchases include ice, fuel, bait, vessel repair, docking fees, insurance, etc. and

Induced effects: sales, income and employment generated by the expenditure of incomes generated in the direct and indirectly impacted sectors of the economy.

Impact estimates derived from input-output models are based on the expenditures associated with a production activity within a single time period, usually one year. Impact estimates do not represent benefit-cost evaluations for a particular activity, and they do not usually represent the present value of stream of future expenditures or revenues.[1]

IMPLAN Professional® (IMPLAN) is a commercially available software package and related databases available through MIG, Inc. (see earlier citation) that allows users to quickly develop regional input-output models for any county or group of contiguous counties or states within the United States. The software runs on IBM-compatible personal computers within Windows® 95, 98, NT, 2000 or XP operating systems. Model development using IMPLAN requires the purchase of the IMPLAN modeling software and a regional data set sold by State at the state or county level.

IMPLAN begins with national I/O tables or matrices based on benchmark studies of the national economy conducted by the Bureau of Economic Analysis of the U. S. Department of Commerce. National I/O tables reflect the use of commodities to produce each industry's output (the use table), the production of commodities by industry sector (the make table), and details on value added and final demands by industry. A coefficient version of the use table (the absorption table) is a set of linear production functions for each industry sector of the national economy. Data are also available on output, employment and value added for each industry sector at the national level. For IMPLAN purposes, economic activities are grouped into 509 different industry sectors following the North American Industry Classification System (NAICS). The IMPLAN data set includes "bridge" tables to allow users to determine which activities are included in a given sector.

To allow the construction of regional models, the IMPLAN database contains statistics on output, employment, and value-added for each of 509 industry sectors in each county of the United States. Regional models may then be constructed any area consisting of a single county or group of contiguous counties within the nation. Regional IMPLAN models use the same production technology as the national model. Mathematically, this means that the production coefficients for the regional industry are the same as the national average for that industry. Regional coefficients may be smaller, however, depending on the mix of industries present in the region in comparison to the nation as a whole. Regional production coefficients reflect both the prevailing technology (from the national data) and whether or not industry inputs are purchased from within the region.

If a particular supplying industry does not exist within the region (employment is zero), then all coefficients reflecting input requirements supplied by that (missing) industry are set to zero, and regional models show those purchases as required imports. For other supplying industries within

[1] Information provided in the overview section is taken from the earlier cited IMPLAN User's Guide.

the region, some downward adjustment may be required based on available supplies relative to total intermediate and final demands for that output. IMPLAN procedures then estimate regional trade flows (imports and exports to and from the region) for each industry sector as part of the process of estimating regional production coefficients. This step is crucial since the size of resulting regional multipliers depends on the proportion of input requirements purchased within the region.

IMPLAN offers the regional analyst three options for estimating trade flows (regional purchase coefficients in IMPLAN terminology) within regional models. The "supply-demand pooling" approach maximizes local purchases and the magnitude of the resulting multiplier by requiring that local needs be satisfied by local production to the extent possible. All local demands for the output of a particular industry (either as intermediate products or final demands) must be satisfied before any of that industry's output is exported from the region. Where an industry's output is insufficient to satisfy local needs, all regional purchases from that industry are scaled downward proportionally and the balance is reflected as imports. This approach eliminates cross-hauling (regional imports and exports of the same good). In IMPLAN terminology, the regional purchase coefficient for a particular sector is set to 1.0 when regional production meets or exceeds regional requirements, and any excess production is shown as regional exports. When regional production is less than regional requirements, the regional purchase coefficient is less than 1.0 and represents the percentage of requirements supplied locally with remaining requirements supplied by regional imports.

A second option within IMPLAN for estimating trade flows is a "location-quotient" based approach. Here the extent to which a region specializes in a particular industry relative to the nation is assessed by calculating the ratio of the percentage of regional employment in a given industry to the same percentage for the national economy. If the this ratio (the location quotient) is greater than 1.0, the region is more specialized in production of that industry than is the nation as a whole, and the regional purchase coefficient is set equal to 1.0 (all needs are met with local production). If the location quotients is less than 1.0, regional purchase coefficients are set equal to the location quotient (less than 100 percent of local needs is supplied locally). In either case local purchases from a particular industry cannot exceed the output of that industry. Compared to the supply-demand pooling approach, the use of location quotients allows for some cross-hauling to occur and multipliers are generally lower.

The third option, and the one set as the default if no choice is made, uses regional purchase coefficients estimated with a set of econometric equations contained within IMPLAN with arguments in the estimating equation being some set of regional characteristics. As with the previous case, regional purchases from any given industry are constrained to equal regional output of that industry. That is, the regional purchase coefficient can never be larger than the one resulting from the supply-demand pooling option.

The final result of the estimating process contained within IMPLAN is a regional input-output model constructed by adjusting national production coefficients to reflect regional differences in production capacity (industry mix). While the underlying production technology remains the same as the national model, the adjustments in the coefficients reflect the degree to which inter-industry product flows are satisfied from within the region, or through imports or exports. These adjusted coefficients determine the magnitude of the estimated regional I/O multipliers. IMPLAN regional models calculate standard I/O Type I multipliers (direct and indirect effects), Type II multipliers (direct, indirect and induced effects), or Type SAM (social accounts matrix) multipliers that capture the effects of institutional transfers within the regional economy. Again, it is important to stress that regional models are based on all the standard I/O assumptions noted earlier, as well as the additional assumptions regarding the uniformity of technology between the region and the nation, and those assumptions associated with the choice of procedures for estimating regional trade flows.

**Defining Study Regions:** Previous sections provided a general discussion of estimating regional input-output models using IMPLAN without explicitly noting the critical step of defining the region for which impacts are to be estimated. As noted, IMPLAN allows regions to consist of geographic areas as small as counties and as large as multi-county or multi-state regions.

To some extent the definition of a region for a particular study depends on the nature of the impact question and the specific need for information. Such needs, however, must recognize that multipliers and resulting impact estimates are dependent on the size (economic and geographic) of the region. Ideally, the region suggested by the IMPLAN User's Guide and by regional economic theory is one where most of the impacts associated with the purchasing activity of firms takes place (a "functional" economic region). For example, in its treatment of the household sector (employment), IMPLAN assumes that employment is local. If in fact the region defined is too small and a large number of workers commute from outside the area, models will over estimate employment impacts. At the other extreme, if the region defined is too large, resulting estimates may not be meaningful for a particular location or political jurisdiction.

With respect to the particular application addressed in this report, the question of regional definition is equally important. A state model (Florida) would provide impacts specific only to the state of Florida with little meaning for any particular county (or community) within the state. On the other hand, individual models for each of the twelve counties along Florida's east coast would likely be unrealistic from the standpoint of the fishing industry and in creating models of functional regions. As noted earlier, fishing activity along Florida's east coast, seems to fall within three regions (Figures 2), which corresponds to functional economic regions defined by the Bureau of Economic Analysis (Figure 3). Alternatively, it may be possible to accomplish an acceptable level of sub-regional specificity in impact estimates by working with a state level model and then proportionally allocating indirect and induced impacts to the three functional regions noted here.

**Adjustments to IMPLAN:** Once regional models are constructed, the IMPLAN software allows users considerable latitude in making adjustments where additional or more accurate data is available for particular regional industries. Users are able to view and edit the regional data set on which IMPLAN bases its calculations (industry output, employment and value added) and incorporate new data into the final model.

Likewise, IMPLAN users can view and edit regional household and institutional demands for commodities. There are nine household sectors within IMPLAN (based on income levels), federal defense and non-defense sectors, state/local government education and non-education sector, and an investment sector. Users may also adjust the amount of sales by a sector going to foreign exports, adjust the margins used for the wholesale and retail trade sectors, and margins for the transportation sectors as well, where those are appropriate.

Finally, and perhaps most importantly for modeling impacts in the fisheries sector, IMPLAN allows users to edit regional production functions for particular industries when sufficient data is available. Similarly, users have the flexibility of adding new sectors, or more precisely, disaggregating existing sectors to provide more precise specifications of regional industries. This feature will be useful for the Florida commercial fishing industry due to wide variations in the nature of the industry by region and targeted species.

It is important to note that IMPLAN data sets already contain much of the data that is readily available from secondary sources. Thus the incorporation of additional data for specific sectors in IMPLAN, usually means that these are primary data. If a more precise I/O model of Florida's fishing industry were desired, it would require data on cost of production for each newly defined harvesting sector as well as information on the product flow between those sectors and all defined dealer and/or processing sectors. Expanding the study to include sub-regions would require a similar data collection effort for each sub-region as well as information on interaction among sectors across regions. All such efforts would likely data sources beyond those routinely carried out for national benchmark studies.

**IMPLAN Fishery Sectors:** The current version of IMPLAN captures fishing related activity in two economic sectors, one for fishing and an additional sector for processing activities. The two sectors are defined as follows:[2]

> **IMPLAN Sector 16 Fishing (NAICS 1141):** This industry comprises establishments primarily engaged in the commercial catching or taking of finfish, shellfish, or miscellaneous marine products from a natural habitat, such as the catching of bluefish, eels, salmon, tuna, clams, lobsters, mussels, oysters, shrimp, frogs, sea urchins, and turtles.[3]
>
> **IMPLAN Sector 71 Seafood Product Preparation and Packaging (NAICS 3117):** This industry comprises establishments primarily engaged in one or more of the following: (1) canning seafood (including soup); (2) smoking, salting, and drying seafood; (3) eviscerating fresh fish by removing heads, fins, scales, bones, and entrails; (4) shucking and packing fresh shellfish; (5) processing marine fats and oils; and (6) freezing seafood. Establishments known as "floating factory ships" that are engaged in the gathering and processing of seafood into canned seafood products are included in this industry.

There may however, be some seafood related activities that would not be captured in these two IMPLAN sectors. Industry classifications are based on the primary activity of a given establishment. Businesses that primarily purchase and resell raw seafood products in a given region could be classified as a part of the Wholesale Trade sector in IMPLAN. Again, this implies that adjusting IMPLAN models for a particular region will require information on the nature of the regional industry and the movement of products between harvesters, dealers, processors and final consumers.

## Review of Modeling Approaches

IMPLAN has been widely used for impact analysis around the county on issues involving commercial fisheries. The section provides a brief review of those efforts as a basis for

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[2] Executive Office of the President, Office of Management and Budget, North American Industry Classification System, United States, 1997.

[3] Farm raising of finfish, shellfish, or other marine animals is classified separately by NAICS and is included in an animal production sector by IMPLAN.

establishing alternative approaches to estimating economic impacts of commercial fisheries along Florida's east coast. Particular attention will be devoted to work by Steinback and Thunberg[4] in developing a multi-regional impact model for commercial fishing in New England and supporting work completed at Woods Hole Oceanographic Institution,[5] work by James Kirkley[6] in developing spreadsheet models using basic IMPLAN multipliers to capture indirect and induced impacts, and a U.S. west coast modeling application called the Fisheries Economic Assessment Model or FEAM.[7].

This literature review is not intended to be exhaustive, rather, the intent is to establish the nature of the modeling problem (a conceptual approach) and identify the major approaches to addressing impact estimation within that conceptual framework. The actual modeling applications mentioned for review in the previous paragraph are examples of different approaches. The FEAM model is not treated in detail since its basic logic is similar to that of the Mid-Atlantic model developed by Kirkley.

**Modeling Fishery Industries: A Conceptual Framework:** The process or challenge of adapting IMPLAN input-output models to fisheries applications can best be understood within a conceptual framework that outlines the modeling issues in a manner consistent with input-output logic. The framework can then be used to assess different approaches to modeling impacts for commercial fisheries.

Input-Output Logic and Product Flows: Input-output models divide the economy into economic sectors and track the movement of goods and services between businesses and between businesses and final consumers. Thus, the first step in applying input-output models to fisheries is to delineate the product flows of interest in a manner consistent with the standard input-output framework. Figure 15 provides an overview of product flows in the context of input-output logic adapted from the earlier cited work by Steinback and Thunberg.

In Figure 15 commercial harvesters of fish and marine products generate sales, employment and income through the harvesting and marketing of fish. Harvesters, in turn, make purchases of the inputs required to conduct harvesting operations (fuel, boat repair, nets, ice, insurance, food,

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[4] Steinback, Scott and Eric Thunberg, "An Approach for Using IMPLAN and its Associated Data Package to Estimate the Economic Activity ("impact") Resulting From Fishery Management Actions. Northeast Fisheries Science Center. NMFS National Social Scientists Workshop, La Jolla, California, February 22-25, 2000.

[5] Woods Hole Oceanographic Institute, Marine Policy Center, "Development of an Input-Output Model for Social Economic Impact Assessment of Fisheries Regulation in New England." MARFIN Project Final Report to National Marine Fisheries Service Grant Number NA87FF0548, March 2000.

[6] Kirkley, James E., "Assessing the Economic Importance of Commercial Fisheries in the Mid-Atlantic Region: A User's Guide to the Mid-Atlantic Input/Output Model." School of Marine Science, College of William and Mary. Report prepared for the Northeast Science Center, NOAA Fisheries, National Marine Fisheries Service, Woods Hole, Ma.

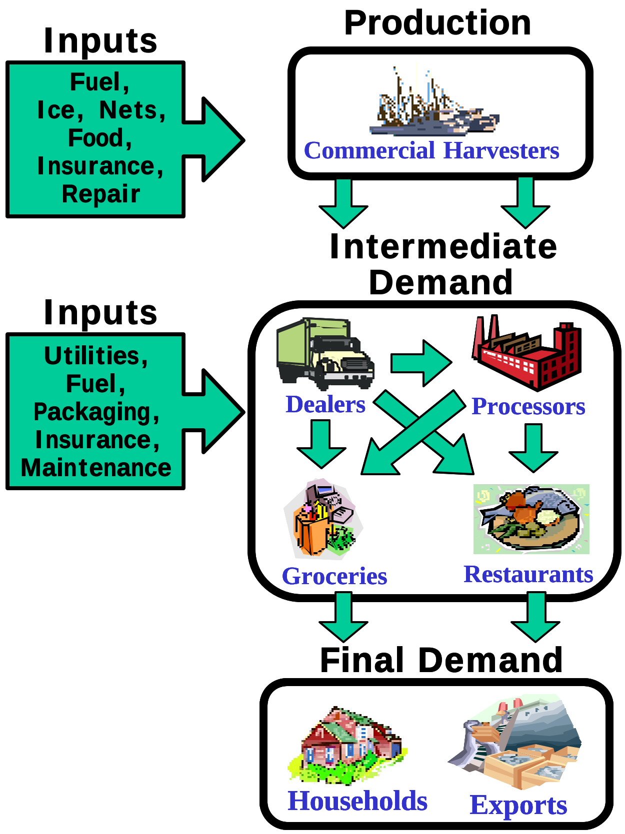
[7] Jensen, William S., "Notes on Using the FEAM Economic Impact Model: A Practitioner's Approach," Prepared for Steve Frese, Economist, National Marine Fisheries Service, May 1998.

etc.). Commercial harvesters sell seafood products to seafood dealers or to seafood processors (direct sales to consumers are not shown here to simplify the diagram), and seafood dealers may resell products to processors. Seafood processors generate sales, income and employment by selling processed products to consumers through other intermediate sectors (grocery stores and restaurants) to exports or directly to final consumers. Seafood dealers generate sales in the same manner by selling to grocery stores or restaurants, directly to final consumers or exports, or to seafood processors. Harvesters, dealers and processors may also be vertically integrated through common ownership or long-term contractual arrangements. Regardless, dealers or processors (or those functions) will make additional purchases to support their operation (utilities, insurance, packaging materials, etc.).

An input-output model reflecting the fishery industry depicted in Figure 15 would have three sectors (commercial harvesting, seafood dealers, and seafood processors) directly involved in the production and processing of seafood. Additional sectors involved in the movement of seafood from producers to consumers would include wholesale and retail trade, restaurants, and transportation (not shown in figure) sectors. The model would have information on sales, income, employment, and value added and input purchases for each producing sector and would show the allocation of sales between intermediate demand (sales to other producing sectors) and final demand (consumers and exports). The transportation and trade sectors would reflect the appropriate margins associated with product movement. Once developed, such an input-output model would fully capture the interactions of the seafood producing and handling sectors with all other sectors of the economy. Model information would reflect purchases by the seafood industry from all other sectors of the economy and sales to all other sectors and to final demand.

<u>Application to Regulatory Changes in Fisheries:</u> As previously noted input-output models like that described in Figure 15 are ideally suited to assessing the economic impacts of changes final demand (changes in consumers sales or exports). Resulting multipliers would trace the effects of such a change backward through the various industry linkages from grocery stores or restaurants to processors, seafood dealers, commercial harvesters and all other sectors directly or indirectly related through input purchases. The model would also capture the induced (spending) effects of changes in income in the various sectors.

Figure 15. Input-Output Logic and Fishery Product Flows




The scenario of a final demand change is not applicable when considering changes in fishery regulations. Such changes are more likely to impact the output of the commercial fishing sector, and the analyst must decide how such a change will affect the output of seafood dealers and processors, and final consumption. Outputs of the forward-linked sectors may be reduced in proportion to the decline in the availability of fish products from the commercial harvesting sector, or, dealers and processors may continue to operate at the same level by substituting other species or other products, or they may increase the use of imported products. Consumers will not likely reduce total consumption, but are more likely to make product substitutes either by consuming other types of seafood or substituting non-seafood products.

The analyst must decide, in dealing with this issue, on the extent to which impacts reflected in the forward linkages are to be captured by any impact analysis. To the extent that such impacts are to be considered, analysts must have information on how the forward-linked sectors respond to changes in product availability. The simplest assumption is that the output of each forward-linked sector will decline in a manner proportional to the output change of the commercial fishing sector (with adjustments for the yield of processed product from a given volume of raw seafood). Product substitution becomes more likely as one moves further down the production/marketing chain, away from the harvesting sector. Within the input-output framework, however, care must be taken to avoid double-counting when considering both harvesting sectors (commercial fishing) and forward-linked sectors (seafood processing).

**Approaches to IMPLAN Applications:** In general, there are two ways in which an analyst might approach the use of IMPLAN to estimate economic impacts of changes in the output of the commercial fishing sectors (or related dealer and processing sectors). In one approach, IMPLAN multipliers are generated for all sectors of a regional economy using standard IMPLAN procedures for compiling regional models. Resulting multipliers for non-fishing sectors are then used outside IMPLAN to estimate impacts associated with independent estimates of expenditures by fishing related sectors (similar to the effort by Kirkley). A second approach focuses on using the "Impact Module" within IMPLAN to calculate impacts of potential changes in fishery output. This approach requires the creation of new fishery and fishery-related sectors and/or the adjustment of existing fishery sectors. The latter approach is embodied in the work of Steinback and Thunberg.

With either of the general approaches an analyst may proceed in a systematic or an ad hoc fashion. The ad hoc approach is usually used to estimate the impacts of specific events in specific locations without regard to the impact of the overall fishery on the regional economy. The systematic approach is associated with the development of comprehensive models at a regional level that capture the impacts (interactions) of the entire fishery related industry. Both the effort by Kirkley and that by Steinback and Thunberg as well as the FEAM model represent systematic efforts to capture the total economic impact of the entire fishing industry within the region(s) of interest. Each general approach is described below after comments related to the estimation of direct impacts.

<u>Estimating Direct Impacts:</u> A key point before addressing IMPLAN applications is to reinforce the point made earlier regarding the direct impacts of changes in the fishery sector. IMPLAN applications in either of the cases mentioned above will require estimates of direct output changes in fishery related sectors. Such changes are made independently of information contained within IMPLAN.

The extent of the direct impact estimates required will depend on the level of analysis selected for the total impact estimates. If the focus is only on the commercial harvesting sector and potential changes generated indirectly with the production of seafood products at that level, then only estimates of direct changes in the value of landings will be required. If the analysis is to focus on the forward-linked sectors, then direct output changes must also be provided for those sectors prior to developing any IMPLAN applications. Further, the fishery model outlined in Figure 15 contains only three fishery related sectors (harvesting, seafood dealers, and processors) and is described in terms of one region. To the extent that additional harvesting, dealer, or processing sectors are specified, or if the analysis is extended to include more than one region, the task of estimating direct changes in outputs, and the data required to do so, expands accordingly.

<u>Kirkley Mid-Atlantic Approach:</u> This approach implicitly begins with the assumption that the fishery sectors (harvesting and processing) within a standard IMPLAN model are not adequate for completing fishery impact estimates for any specific component of the fishery industry in any specific region. As noted earlier, such an assumption is likely valid in that any particular component of the fishery industry will depart rather substantially from standard input-output assumptions of homogenous sector outputs and similar production technologies. This approach allows the analysis to proceed without requiring adjustments to information contained within IMPLAN, and impact calculations can be performed using spreadsheets.

The general approach uses a regional IMPLAN model to calculate multipliers for those sectors of the regional economy impacted by expenditures of the fisheries sector. Multipliers are then used with separate estimates of expenditures by fishery sectors to estimate the impact of fishery activities. The basic idea is that an expenditure by a fishery related sector represents a direct impact on some other sector of the regional economy and that sector's activity then has an indirect and induced impact captured by its multiplier. A simple example can be illustrated with some examples of typical expenditures and sector allocations taken from Kirkley.

Typical expenditures by a commercial fishing sector would include purchases of goods (gear, hardware, supplies, electronics), repair expenses (gear, nets, boats, engines), trip expenses (groceries, fuel, ice, bait), fixed expenses (moorage, licenses, insurance, accounting, etc.) as well as labor expenses (crew and captains share) and the owner's profit. Again following Kirkley, expenditures would be allocated to appropriate IMPLAN sectors (Table 2). The multiplier for each IMPLAN sector would then be used with the expenditure by fishery industries in that sector to estimate the impact. For example, expenditures by commercial harvesters for vessel maintenance would be allocated to the Boat Building and Repair sector within IMPLAN. Multiplying the dollar expenditure by the Boat Building and Repair multiplier would capture the indirect and induced effects of spending on vessel maintenance within the regional economy. Total impact would be the summation over all sectors impacted by fishery expenditures. To fully capture impacts, the share of expenditures representing labor income and profits must also be converted to expenditures and allocated to appropriate IMPLAN sectors.

This approach requires knowledge independent of IMPLAN on expenditures associated with harvesting seafood products, and expenditures must be correctly allocated to the appropriate IMPLAN sectors. Further, allocated expenditures must be reduced by the proportion of input purchases that take place outside the region to avoid over estimation of impacts. In every case, whether expenditures represent crew income and profit or vessel operating costs, when purchases involve margin sectors within an input-output framework (trade and transportation), efforts must be made to allocate the margins to the appropriate sector.

While the discussion above is in terms of a commercial harvesting sector, attempts to include estimates associated with seafood dealers or processors would require similar information and actions for those sectors. The projected change in output of the commercial production sector would first have to be translated to an output change at the dealer level based on the yield of wholesale or processed product from a given volume of raw seafood product. Information on expenditures for other production inputs by dealers or processors would also be needed. Again, care must be taken at this step to avoid double counting impacts. Double counting can be avoided by estimating dealer or processor impacts net of the value of the seafood product at the harvester level.

**Table 2: Typical Fishing Expenditures and IMPLAN Sectors**

| Expenditures | IMPLAN Sectors |
|---|---|
| Bait | Commercial Fishing |
| Ice | Manufactured Ice |
| Maintenance and Repair | Boat Building and Repair |
| Insurance | Insurance |

| | |
|---|---|
| Rent | Real Estate |
| Margin allocations | Wholesale & Retail Trade |
| Margin allocations | Transportation & Food Stores |

Steinback-Thunberg New England Approach: The Kirkley Mid-Atlantic approach discussed in the previous paragraphs generally requires little expertise at using or adjusting IMPLAN models. Multipliers are extracted from a standard regional input-output model generated in IMPLAN and then exported to spreadsheet software to complete the impact analysis. The Steinback-Thunberg approach directly modifies the number of sectors, production functions, trade flows, and distribution of outputs within IMPLAN to estimate a regional model that reflects the characteristics of those sectors in the regions that harvest, process and distribute seafood products.

This approach requires much more familiarity with the modification and use of the IMPLAN software during model development. Data similar to that on expenditures used in the Kirkley approach will be necessary to estimate new production functions for fishery related sectors in a Steinback-Thunberg type IMPLAN model. By the same token, in the process of specifying the new IMPLAN production function, expenditure data must be allocated to the appropriate IMPLAN sectors, and adjustments will be necessary when direct expenditures by the fishing related sectors take place outside the region of interest. Information will also be required on the movement of product between fishery related sectors (i.e.; harvesters, seafood dealers, and processors), between each of these sectors and the various components of final demand (consumers and domestic and foreign exports), and on the handling of final products by various margin sectors (trade and transportation) between producers and consumers.

Once the regional models are constructed, this approach will have the same problem as noted before; the model is demand driven while the problem is more one of assessing the impact of changes in supply at the harvester level. The same decisions must be made about whether or how many of the forward-linked sectors to include in the impacts, and the same level of care is required to avoid double counting impacts. Impacts can, however, be calculated using the standard impact module within the IMPLAN software which takes full advantage of the complete interaction between sectors within the model and allows a more detailed assessment of impacts across sectors. Income, for example, would accrue to the household sector and be expended in accordance with model coefficients without requiring the separate step of calculating household expenditures. Other fishing expenditures by seafood sectors will be distributed by IMPLAN based on the estimated production functions for each sector. The percentage of those products supplied locally, however, will be determined by the IMPLAN regional purchase coefficient for the supplying sectors and will require verification to make sure that the adjusted model allocates the correct proportion of expenditures to regional sectors as opposed to regional imports.

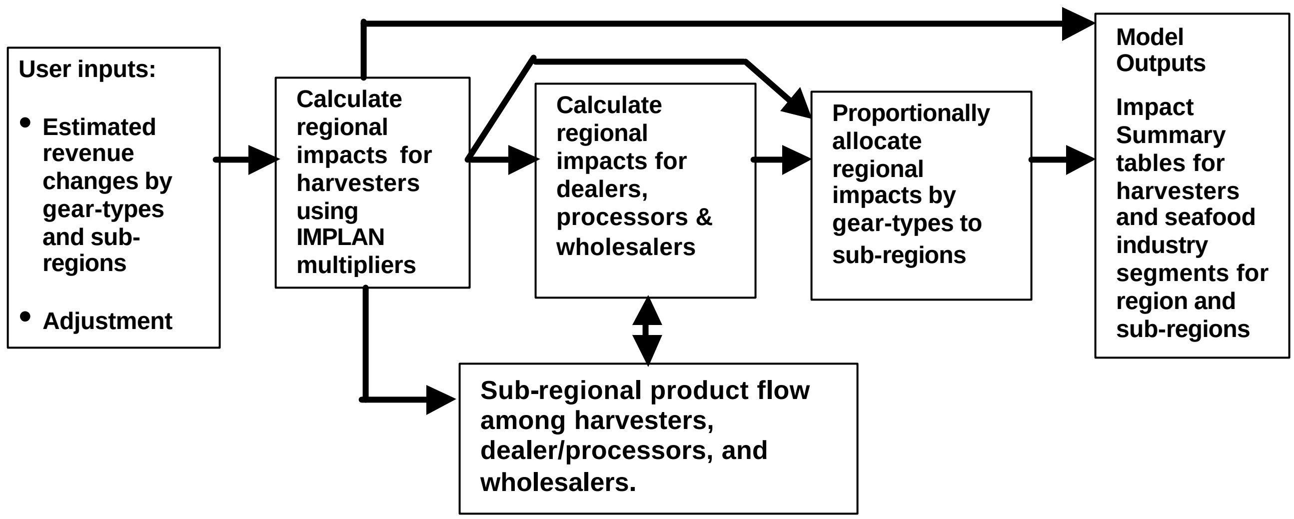
**Sectors, Regions and Applications:** The issue of the number of sectors and specific regions is best addressed with reference to and further explanation of the two specific models referenced earlier, the works by Kirkley and that by Steinback and Thunberg. Both represent systematic attempts to capture the impacts of the entire fishery at the regional level, both disaggregate commercial fishing into a number of harvesting sectors, and both consider sub-regional impacts within the broader Mid-Atlantic and New England regions. The general logic of each model will be presented first. This will be followed by a more detailed discussion of the delineation of sub-regions and sectors.

Figure 16 depicts a general outline of the approach employed by Kirkley. The model is multi-sector and multi-region, and the user is required to specify the value of landings for each sector in each region. Spreadsheets then calculate the total impacts using multipliers for regional sectors estimated using standard IMPLAN input-output models. In terms of forward linkages, the model also calculates within the spreadsheets the impacts associated with activities for seafood dealers, processors and wholesalers with accounting for product flow among harvesters, processors, and dealers across sub-regions. The final step in the model is to allocate total impacts to sub-regions of interest. Total impacts of fishing related activity are first calculated for the multi-state, Mid-Atlantic region and then allocated to sub-regions based on the existing income, employment or output for each sector relative to that of the larger region. The Kirkley model does not include the impacts associated with the final distribution of seafood products. The model does take the steps necessary to avoid double counting when dealer and processor sectors are included.

The New England model developed by Steinback and Thunberg is in many ways similar to the effort by Kirkley for the Mid-Atlantic region. For fishing related industries the model is multi-sector and considers several sub-regions within a five-state New England region, and like the Kirkley model it captures the impacts of harvesting , seafood dealers and processing. Impacts are calculated for the entire New England region and then allocated to sub-regions using either employment, income or output in the sub-region relative to the larger region (Figure 17).

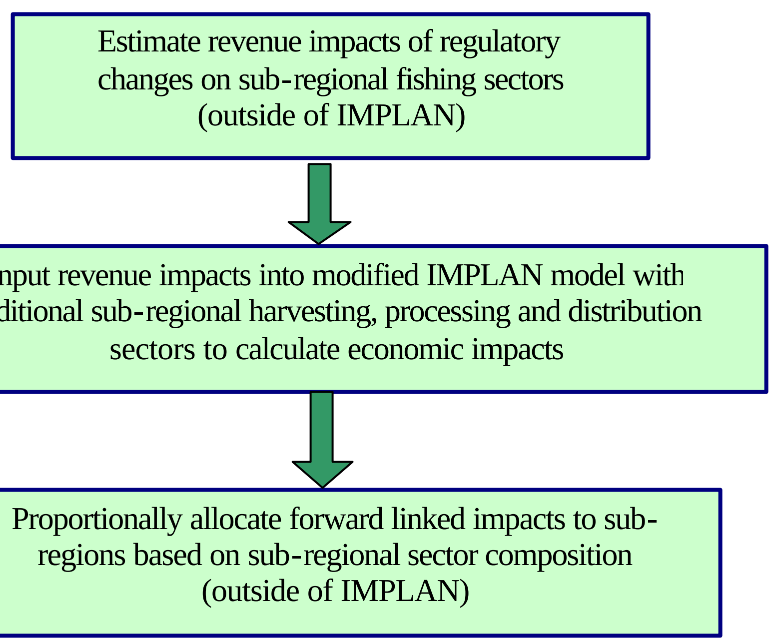
The key difference is that the Steinback-Thunberg model adjusts all fishing related sectors within the New England input-output model estimated using IMPLAN. In this manner all impact calculations take place using the standard IMPLAN impact module rather than separate from IMPLAN as in the Kirkley approach. Sub-regional impacts are then allocated proportionally as in the Kirkley approach.

**Figure 16: Schematic of Mid-Atlantic (Kirkley) Impact Model**




Adapted from James E. Kirkley, "Assessing the Economic Importance of Commercial Fisheries in the Mid-Atlantic Region: A Users Guide"

**Figure 17. Schematic of New England Fisheries (Steinback-Thunberg) Impact Model.**



**Defining Fishing Related Sectors and Sub-regions:** Both the Mid-Atlantic and the New England fishery models are multi-sector in nature and related in the sense that the New England model served as a guide for defining sectors in the Mid-Atlantic model (Table 3). Sectors are defined based on the types of fishing gear employed with the idea that it is the choice of technology that determines the expenditures and the ultimate impacts of fishing on the regional economy. Both models address impacts across several sub-regions of the broader Mid-Atlantic (seven state) or New England (five state) region. The Mid-Atlantic region model addresses 12 distinct sub-regions while the New England model sub-divides the region into 11 coastal sub-regions and one non-coastal sub-region containing the rest of New England. The models then estimate impacts for the broader region and allocate those impacts to the sub-regions contained within the model.

**Table 3. Fishing Related Sectors: Mid-Atlantic and New England Models**

| Mid-Atlantic Model | New England Model |
|---|---|
| | |
| Inshore Lobster | Inshore Lobster |
| Offshore Lobster | Offshore Lobster |
| Large Bottom Trawl | Large Bottom Trawl |
| Medium Bottom Trawl | Medium Bottom Trawl |
| Small Bottom Trawl | Small Bottom Trawl |
| Large Scallop Dredge | Large Scallop Dredge |
| Medium Scallop Dredge | Medium Scallop Dredge |
| Small Scallop Dredge | Small Scallop Dredge |
| Surf Clam/Ocean Quahog | Surf Clam/Ocean Quahog |
| Midwater Trawl | Sink Gillnet |
| Bottom Longline | Diving Gear |
| Other Gear | Midwater Trawl |
| Pots and Traps | Pots & Traps (other than lobster) |
| Gill Nets | Bottom Longline |
| | Other Mobile Gear |
| | Other Fixed Gear |
| | Hand Gears (rakes, hoes, etc.) |

The key difference between the models, as noted before, is that Steinback and Thunberg first estimate a regional model (for New England) and then expand that model by including specific sectors for each gear type noted above in each sub-region. A seafood dealer and two processing sectors is also defined for each sub-region for a total of 20 sectors for each sub-region. The expanded New England model (using the current NAICS aggregation for IMPLAN) would begin with the original 509 IMPLAN sectors. The fishing-related sectors would then be disaggregated to include the new sectors. In terms of total sectors, this effort would add 20 sectors times 11 sub-regions or 220 new sub-regional sectors. Other sectors determined to be fishery related were also disaggregated. The final version of the New England model resulted in an IMPLAN model with more than 900 producing sectors. These additions require not only disaggregation of the sectors at the sub-regional level, but they also require adjustments to the national data tables within IMPLAN (in Microsoft access) to allow the IMPLAN software to recognize the expanded number of sectors and reformulate the regional models with the adjustments.

The Kirkley approach is similar in terms of data requirements. Fourteen gear type sectors are defined for 12 coastal sub-regions within the Mid-Atlantic region. To use the model, as with the New England model, information is necessary on the value of landings (fishery output) for each sector in each sub-region. Similar to the New England model, the Kirkley approach does not include impacts in restaurants and grocery stores but does account for seafood dealers and processors, so output data for those sectors, by region, is necessary as well. Once the Kirkley model is constructed in spreadsheets, it can be used without knowledge of IMPLAN, and the initial construction of the model requires little knowledge or expertise with IMPLAN. This is in contrast to the approach with the New England model where construction requires a user with a high level of sophistication in using IMPLAN, Microsoft Access, and spreadsheets.

Both the Mid-Atlantic and New England model are similar in that impacts for fishery related sectors are calculated at the multi-state, regional level. Both then allocate the indirect and induced portion of total impacts to sub-regions in proportion to income, employment or output in each sector within the sub-region relative to the larger region. In effect, both consider sub-regions in the analysis, but neither approach represents a truly multi-regional model.

A potential shortcoming of both the New England model and the Mid-Atlantic model relates to the available data to support the modeling application. While no attempt is made here to evaluate the data contained within each model, it appears likely that the level of detail in terms of the number of sectors and regions is greater than can be supported by the available data. For example, for each particular harvesting technology or gear type defined as a sector within the New England model, one sees 11 IMPLAN sectors, one sector for each gear type within each sub-region. For example, the Large Bottom Trawl sector would be defined for Region 1, Region 2, Region 3, etc. until the 11 sectors were completed. Each sub-regional bottom trawl sector could, in theory, have a unique production function and production distribution pattern compared to the bottom trawl sector in other sub-regions.

The estimation of unique sub-regional sectors would suggest that either production expenditures within a particular gear type sector differ across sub-regions or that the distribution of output from the harvesting sector differs across sub-regions. The first appears less likely since harvesting expenditures are determined, for the most part, by the technology employed and seems less likely to vary across sub-regions. Product distribution patterns could vary across sub-regions for a number of reasons: different species taken with the same technology, variations in the location of processing facilities across sub-regions, or variations in the value of sales by sub-regional harvesters to dealers located outside the sub-region. There are likely other possibilities for explaining sub-regional variations, but in any case, the definition of different sectors by sub-region would require both detailed knowledge of the sub-regional industry and sufficient data to specify differences in either harvesting expenditures or product distribution. For a particular gear type sector, to the extent that the production functions and proportional product distributions are the same across sub-regions, the impacts per unit of output value will be the same since the impacts for each sector are assessed within the larger regional model.

One additional difference should be noted between the New England model and the Mid-Atlantic model. The latter is constructed using spreadsheets designed to be used by individuals with little or no knowledge of underlying IMPLAN models. The spreadsheets contain the necessary proportional expenditure and product distribution coefficients, and users are required only to enter the value of landings by gear type sector to calculate impacts. The New England model, on the other hand, is more complex in its application of IMPLAN. There is some possibility of making such a model available to IMPLAN users, but such an effort would require either previous knowledge of IMPLAN or training to develop analysts comfortable with its use. More likely, the New England type model would be developed within a regional center and remain in that center for use by experienced analysts. If widely used, however, the approach of the Mid-Atlantic model would involve some attention to logistics regarding model updates. The IMPLAN data set is updated annually to reflect the latest national and regional data on output, value added, income and employment by sector. If the spreadsheet models were to remain current, then all versions of the models in use would require new multiplier data to be incorporated each year.

## Conclusions and Recommendations

Conclusions and recommendations will be discussed at this point with regard to estimating impacts associated with commercial fishing along Florida's east coast. Points offered are based on the assumption that any modeling effort will be comprehensive and ongoing. In other words, the developed model will be applied across all species and harvesting activities in the fisheries for the indefinite future, as opposed to short-term ad hoc efforts to estimate the economic impacts of a specific regulatory change.

**Adjustments to standard IMPLAN models will be necessary to adequately capture the impact of fishery related industries on Florida's East Coast.** Given the large number of species harvested and the variety of technologies (gear types) employed, the fishery sector within the standard IMPLAN regional model will violate the assumptions that a sector produces a homogenous product with a homogenous production technology. Further, due to the same type of variation across regions or sub-regions, the distribution (or allocation) of products from the harvesting sector to other intermediate sectors, domestic and foreign exports, and final consumers is likely to vary widely from that in a regional model based on national averages. The industry is complex, and that complexity likely rules out the use of generic models that can be used without significant refinement.

Given the complexity and time horizon of fisheries regulation programs, the strategy chosen in modeling the economic impacts of regulatory changes must also consider the skill and time required to maintain and update the model, apply the model to different impact questions, and to interpret the results. These modeling capabilities could be implemented using National Marine Fisheries staff or they could be contracted to outside public or private entities. In either case, the key to success is building or acquiring the human capital to carry out development, applications and modification of the I/O models over time. It will also be critical that the analysts working on impact issues be familiar with Florida fisheries, related industries and their regulations, or have close working relationships with individuals that do.

**The final form of the adjusted IMPLAN model will depend on the number of commercial fishery harvest sectors, the number of regions or sub-regions defined within the State, and the number of forward linked industries to be included.** These choices will depend on the degree of geographic and sectorial detail desired, and the degree of detail desired in tracing the linkages between fishing related sectors and other sectors of the regional economy. Data requirements for model estimation will increase proportionally as the number of sectors, regions and forward-linkages are added to the model. Specific recommendations on these different aspects of model design are discussed below.

<u>If the decision is made to incorporate additional fishery harvesting sectors, seven gear type sectors could be used to represent approximately ninety percent of fishery output based on the value of landings.</u> This, however, must be viewed as a preliminary consideration based on a cursory review of the data on value of landings by gear type along Florida's east coast. Given the variety of species landed and the variation of gear types and methods employed, the delineation of sectors is one of the more challenging aspects of IMPLAN applications to fisheries. Certainly, defining sectors is a function of having (or collecting) the data necessary to specify production functions. More importantly, the challenge is to group together those types of activities that generate similar expenditures per unit of output in terms of the types of inputs required and the level of expenditures on each. Once a particular fishery is included in a specific sector, then changes in the value of output for that sector in the resulting model should reflect the actual changes in expenditures if the catch of that species decreases (or increases) because of some regulatory change. The final choice of sectors should come after a thorough review of the data by analysts with expertise in input-output modeling and those with detailed knowledge of the fishing industry. Further, the final sector delineation would require some effort to "ground truth" the estimated production coefficients with actual expenditures by selected businesses in that sector.

<u>Three geographic regions corresponding to functional economic areas 29, 30 and 31, as defined by the Bureau of Economic Analysis (Figure 3), would likely be more than adequate in capturing the geographic variations in fishing activity along Florida's east coast.</u> Fishing activity along Florida's east coast tends to be concentrated around three locations. These include the Jacksonville area towards the northern part of the state, the Volusia –Brevard county area near the center of the state, and the Miami-West Palm Beach area to the south. Using geographic sub-regions smaller than the BEA regions would likely result in models that would be less realistic from the standpoint of the fisheries industry and from their inherent economic functionality. The decision will depend on the degree of geographic detail desired, the extent to which forward-linked sectors are to be included, and the degree of detail desired in the ability to trace linkages between fishing related sectors and other sectors of the regional economy. From a geographic perspective, IMPLAN will allow models for areas as small as counties or as large as the entire state or any combination between the two that considers groups of contiguous counties.

A practical alternative to developing a model based on BEA Economic Areas might be to use a state-level model for Florida with 7 to10 fishery harvesting sectors based on gear type, a seafood dealer sector, and a processing sector. As noted earlier, expenditures by harvesting sectors are likely to be highly correlated to the technology and are not likely to vary much across sub-regions of the state. Thus, production functions estimated at the state level would reflect expenditures at the regional level given a sufficient number of harvesting sectors. This approach could provide a comparable level of sub-regional detail as a model with sub-regions explicitly incorporated into the sectoring scheme. Direct impacts could easily be identified with sub-regions based on estimates of the value of landings for different parts of the state. Indirect and induced components of total impacts could then be proportionally allocated to sub-regions following the procedures used in the Mid-Atlantic and New England models. This alternative regional-sectoring approach would greatly reduce the complexity and data requirements of the modeling effort.

Adjusted and/or additional IMPLAN sectors may be required to represent forward-linked fishery industries. Additional information on marketing channels for Florida seafood may be required prior to making decisions regarding the nature of required adjustments to the IMPLAN fish-processing sector and whether or not to include one or more additional sector for seafood dealers, brokers and distributors. These sector decisions will require information on the exact nature of the activities engaged in by each type of firm. Sufficient knowledge to decide on the number and type of dealer/broker sectors could likely be gained through interviews with selected firms within each of the types of firms. It is then likely that more detailed surveys or other data collections activities would be required to specify product movements in more detail with respect to values and to estimate expenditures (production coefficients) for each forward-linked sector specified.

Since input-output models of the type produced by IMPLAN are demand driven, care must be taken to avoid double-counting impacts when forward-linked industries are included in the model. I/O models are ideally suited to the estimation of impacts associated with changes in final demand, where impacts are then traced backwards through the production change to calculate indirect and induced impacts. Regulatory imposed changes in fishing industries, however, usually result in changes in the output of the harvesting sector, the producer of raw product. Such reductions clearly impact the output of forward-linked sectors such as dealers and processors of seafood, but analysts must decide on the sectors to include in any analysis, how to include those sectors, and how to avoid double counting.

Data requirements for model development and application will increase with the number of harvesting sectors, sub-regions, and forward-linked sectors added to the model. Increasing the number of harvesting sectors increases the data requirements by the number of sectors included. The analyst will be required to specify production functions or expenditures for each new sector, delineate product flows to forward-linked sectors, and specify interactions between sectors where necessary. The inclusion of additional sub-regions multiplies the data requirements of the model. Data to specify production coefficients and product distribution patterns would be necessary for each sector included in each sub-region. Data will also be needed to represent the interactions between sectors across sub-regions. For each forward-linked sector added to the model, data will be required to specify its production function (just like harvesting sectors). Additional forward-linked sectors will also require information on product flows to other sectors in the marketing channel and to final consumers.

**The recommended approach follows that of Steinback and Thunberg in the New England model, but reduces its complexity by focusing on fewer sectors and sub-regions.** This simplified approach will help avoid much of the complex and tedious process of adjusting the national data tables within IMPLAN. This approach is also more feasible in terms of data requirements. If it were decided to model the State as a single region, some degree of geographic specificity could still be achieved though a sub-regional allocation procedure.

# The Dynamic Transformation of Regional Economy of Texas in the 1990s: A GIS-Based Economic Modeling and Analysis

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## Introduction

In the U.S., the digital economy led by the information and communication technology (ICT) emerged quickly in the 1990s (Tapscott 1996; Standage 1998; Cohen, Delong, and Zysman 2000). The digital economy is expected to be the engine of the economy and to lead the country into an information age in the 21st century (USDOC 2002). The early study of the information activities of the U.S. economy can be traced to Machlup's (1962) seminal work of the measurement of knowledge content in the economy. Following Machlup's footprint, a considerable amount of studies have been dedicated to conceptualize and quantify the emerging digital economy and information society, most prominently in the U.S. and Japan (Masuda 1982, Rogers and Larsen 1984, Bell 1973, Porat and Robin 1977, Machlup 1984, Williams 1988, Dordick and Wang 1993, Norman 1993, Machado 1994, Machado and Miller 1997, Grimes 2003). There are a growing number of cities, states, regions, countries or even multi-national blocs are plotting their way into the digital economy and information age (Hudson and Leung 1988, Madon 1997, Engelbrecht 2000, Kuo and Low 2001, Lim 2002).

In the state of Texas, political and business leaders have been worked for decades to diversify the economy to offset the loss caused by the declining of the petroleum industry. Information and communication technology (ICT) industries have been recommended as a marked area of growth for the state. In the beginning of the new millennium, the decision has been proven to be very farsighted evidenced by the success stories of Dell Texas Instrument, the development associated with NASA, and the coming of ICT giants such as IBM and Motorola. The most noteworthy event, however, is the quick rise of Austin as a major technopolis (specialized in ICT sectors) in the United States since the 1980s.

The efforts to boost the state economy were fruitful. The decade of the 1990s was a period of sustained economic growth for Texas. An average annual increase of 3.0 percent of job surge throughout the 1990s resulted in an unprecedented 9.31 million jobs by the end of the millennium. At the same time, the unemployment rate dropped from 7.7 percent of 1992 to 4.5 percent by the end of the 1990s, a 20-year low. In addition, Texas economy continued to shift away from goods-producing jobs during the 1990s. The share of goods-producing jobs dropped

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from 29.4 percent in 1980 to 21.4 by 1990, and to 19.3 percent by 2000. The service-related jobs, on the other hand, constituted a larger slice of the job pie (State of Texas 2004).

Just like California or New York, Texas can a whole other country by itself according the key economic indicators. Featuring such an expanse and variety of land, climate, topography, cultures, the economy of Texas is as diverse as it is immense. The thirteen regions of Texas (Table 1, figure 1) all have their unique geographic background, economic structure, employment pattern, and regional comparative advantages. It is obvious that diversity is behind each region's general economic growth during the 1990s.

The primary objectives of this paper are three-fold. The first is to examine the spatial economic transformation in Texas. The second is to test the assumption that there is a trend of "informatization" in the context of the measurement of the information economy. The third is attempt to establish a new analytic framework to conduct the above analysis through the integration of geographic information systems (GIS) and conventional economic analysis and modeling tools such as Input-Output (IO) analysis and extended shift-share analysis. As such, this paper is organized into five parts. Following a brief introduction, the second part discusses some conceptual and measurement issues about the information economy. The third part presents the methods and data used in the empirical study, followed by the results in the fourth part. The fifth part concludes with the suggestion of future study.

## Conceptual Framework

### *The digital economy*

The digital economy is a fuzzy concept, with many similar expressions such as "innovation economy," "network economy," "weightless economy," "knowledge economy," "e-economy," and "new economy" (Cohen, Delong, and Zysman 2000). Yet the digital economy does reflect three distinctive features of economy: 1) the revolutionary development of the ICT sectors and their tremendous impacts on other economic sectors, 2) the exponential growth of Internet users and Internet-based business (also widely known as electronic commerce or E-commerce), 3) the globalization of business and growing flexibility for both producers and consumers at every expanding spatial and temporal scale (USDOC 1998, 2002; Pohjola 2002).

### *The information society*

The concept of the information society is gradually formed based on several classic work including Tadeo Umesao' forecast of the appearance and growth of information sector in 1963 (Wang and Dordick 1993), Daniel Bell's theory of post-industrialism (1976), Dordick and his colleagues' study on "marketplace on the network" (Dordick et al. 1981, Dordick and Wang 1993), and Frederick Williams' proclamation of the arrival of a communication revolution (Williams 1982).

Similar to the concept of digital economy, the concept of the information society also has certain ambiguity and uncertainty. According to Drodick and Wang (1993), there are two paths of conceptualization regarding the idea of the information society. One path seeks to relate the increasing sophistication of technology and planning to the emergence of a new society exemplified by the work of Rolf Jacques Ellul (1964), Dahrendorf (1975) and Daniel Bell

(1976). Bell's post-industrial society[2] has five major characteristics: 1) a shift from a goods-producing economy to a service-producing one, 2) an increase in size and influence of a class of professional and technical workers, 3) a society organized around knowledge, particularly theoretical knowledge, 4) management of technological growth becomes a critical task, 5) an emphasis on the development of methods of intellectual technology.

The other path focuses more on the growing importance of information- or knowledge-based industries in the economy, such as the work of Umesao (Dordick and Wang 1993) and Masuda (1981) in Japan, and Machlup (1962, 1972, 1984), Porat and Robin (1977), and Machado (1994) in the United States, and Schreyer (2001) in five OECD countries. Masuda (1981) believes information values, rather than material values, are the driving force of the information society. For Machlup, Porat, and Machado, the essence of the information society is the continuous growth of information-related activities, jobs, and end products. More recently, Manuel Castells's the information age trilogy (Castells 1996, 1997, 1998) provided a monumental, coherent, and comprehensive account of the economic, social, personal and cultural changes of the information age.

### *The measurement issues*

Theoretical debates are important, but empirical studies are equally essential to supply critical evidence to approve or refute theories and to point out directions for future studies. Consistent measurement makes it possible for spatial and temporal comparisons that help better understand trends and patterns of development. To measure information society, There exist three most widely used indicator systems - infrastructure, economic and social (Dordick and Wang 1993). The economic measurement is briefly discussed below. The other two systems are left for a separate discussion outside this paper because they are not directly relevant to the major theme of this paper.

Sectoral analysis of information workforce and information contribution to the total economic output is a common approach to measure the economic scope of the information society. Kusnetz (1957) first expressed the concern about the workforce engaged in the production and distribution of knowledge. Umesao introduced the concept of the information industries in 1963 (Dordick and Wang 1993). Machlup (1962) defined and studied the production of knowledge and its importance to the U.S. economy He not only measured the share of knowledge industries of the GDP, but also estimated the percentage of the labor force engaged in the industries. Bell (1976) studied knowledge industries using narrower definitions, arguing that Machlup's approaches were too broad to mislead. Machlup's analytical approach was later refined and further applied in several other studies both in and outside the U.S. (Porat and Robin 1977, Lange and Rempp 1977, Wall 1977, OECD 1981; Katz 1986, Jussawalla et al. 1988,). These studies provided rich evidence about the growth of the information sector. However, they also suffered the two common problems: 1) uncertainties related to the definition of information industries (sectors) and information employment; 2) the lack of direct link between the growth of the information sector and information society.

[2] Bell (1973) argued that he preferred a traditional term of postindustrial society rather than information society because the traditional term kept the link between the old and new society.

The input-output (IO) analysis was originally proposed to record the transactions (demands) among the economic sectors (Leontief 1941). IO analysis has several advantages as an analytic tool: 1) standard and longitudinal data at different geographic and temporal scales are relatively readily available and accessible, 2) multiple rather than single measurement can be performed, and 3) the interactions among various sectors of an economy can be measured. Compared to the above measurement tools, relatively few studies have adopted the IO analysis to measure the information economy (Robin and Taylor 1981, Karunaratne 1986, 1991, Machado and Miller 1997). This study makes an effort to incorporate IO analysis to measure the economic transformation. The reason is very simple: the method can be applied on both upper (e.g., state and national) and lower (e. g., county) level of geographic regions, making it easier to compare the results across temporal and spatial scales.

## Method and Data

*Geographic Information Systems (GIS)*

A GIS is a system of hardware, software, data, people, organization and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth (Dueker and Kjerne, 1989). The first GIS in the world was developed for the Canadian federal government in the 1960s to manage forestry resources (Tomlinson, 1984). The wide applications of GIS in social and economic researches started in early the 1990s with the dramatic increasing of performance/cost ratio of computer hardware, maturing of Graphic User Interface (GUI) technology, and the enhancement of spatial analysis and modeling functions of GIS software (Marble 1991, Scholten and Padding 1990, Worrall 1992, Sui 1998). However, Compared to the GIS applications in the fields like environmental modeling, urban planning, and natural resource management, much fewer studies have been dedicated to the integration of GIS into social and economic-related studies. The limitation was caused by two major reasons: 1) the lack of sophisticated analytic and modeling tools of the current generation of GIS (especially those commercial packages), 2) the skepticism, criticism, or even attacks to the intellectual core of GIS from some human geographers and social scientists (Lake 1993, Pickles 1995).

However the focus of this paper is not to discuss the advantages and limitations of current generation of GIS, but is rather to utilize the benefits of GIS to implement economic analysis. Among four different approaches of integrating GIS with other modeling tools (Sui 1998), a loose couple model was adopted in this study. More specifically, economic analysis programs and GIS were run separately; they were integrated via data exchange. This approach saves a lot extensive, and sometimes redundant, programming efforts at the cost of frequent data shuffling and conversion (Figure 2).

*IO analysis*

The essence of the IO model is that complicated interactions within an economy could be approximated by proportional relationships between industrial sectors. Further, the production level of each commodity is determined by the final use of output and the assumed production structure. One noticeable advantage of the IO analysis is its flexibility to investigate problems in different spatial and temporal scales. The linear nature of the IO model does limit the scope of its application, but never excludes it from popular applications in solving social, economic, and environmental problems (Miller and Blair 1985, Hawdon and Pearson 1995).

the primary IO model can be noted as

$$X = (I - A)^{-1} Y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where

$X$ : gross output vector

$A$ : technical coefficients matrix

$Y$ : final demands vector

$I$ : $n \times n$ identity matrix

$(I - A)^{-1}$: Leontief inverse matrix

Since the early 1950s, enormous efforts have been made to solve regional and multiregional macro economic problems using IO analysis (Isard 1951; Moore and Petersen 1955; Hirsch 1959; Emerson 1969, 1971; Giarratani, Maddy, and Socher 1976; Polenske 1980; Miernyk 1970, 1982; McGregor, Swales, and Yin 1996; Li and Ikeda 2001; Lenzen et al. 2003). IO analysis was later extended to study the natural resource allocation and pollution abatement issues (Lofting and McGauhey 1963, Cumberland 1966, Leontief 1970; Laurent and Hite 1971; Giarratani and Thompson 1974; Janicke et. al 1989; Hawdon and Pearson 1995; Lave, Cobas, Hendrikson, and Mcmichael 1995; Matthews 1999; Steenge 1999). The latest expansion of IO analysis is on the social and demographic aspects of the input-output economics (Stone 1970, 1971, Duchin 1998).

*Shift-share Analysis*

Shift-share analysis is a well-established analytical tool originally used to study regional employment change (Barff and Knight 1988, Wright and Ellis 1997). The basic shift-share analysis is easy to interpret and implement. Its application has been extended by geographers, regional economists, urban planners, and policy analysts in various social and economic issues such as evolution of regional industrial structure (Park and Lewis 1991, Haynes and Dinc 1997, Hanham and Banasick 2000,), policy impacts on regional growth (Tervo and Okko 1983, Sui 1995), and population studies (Plan 1987, 1992, Ishikawa 1999). The essence of traditional shift-share analysis is that the changes of local economy can be decomposed into both local and parental factors such as industrial mixtures and growth rates. Shift-share has been widely accepted as a descriptive model even though it seems to be more problematic to be adopted as a prediction tool (Dinc and Hanes 1999).

Shift-share is used in this study to fulfill two objectives. The first is to differentiate leading/lag regions for certain economic sector during the studied period reference to the state average. The second is to identify the degree of dependence (high/lower reference to the state average) of economic sectors in question in a particular region. Here shift-share analysis is treated as a basic descriptive rather than a more sophisticated planning or prediction tool.

By incorporating both Arcelus's extension (Arcelus 1984) and Esteban-Marquillas's concept of homothetic employment (Esteban-Marquillas 1972), the growth of sector *i* in region *j* ($?E_{ij}$) is decomposed of four major components, state growth effect ($SG_{ij}$), state industrial mix ($SI_{ij}$) and regional growth effect ($RG_{ij}$), and regional industrial mix ($RI_{ij}$).

$$?E_{ij} = SG_{ij} + SI_{ij} + RG_{ij} + RI_{ij} \quad (1)$$

$$RG_{ij} = E_{ij}^{H}(P_{nj} - P_{nN}) + (E_{ij} - E_{ij}^{H})(P_{nj} - P_{nN}) \quad (2)$$

$$RI_{ij} = E_{ij}^{H}[(P_{ij} - P_{nj}) + (E_{ij} - E_{ij}^{H})][(P_{ij} - P_{nj}) - (P_{in} - P_{nN})] \quad (3)$$

See Appendix A for the explanations of symbols in equation (1) - (3).

By inducing these extensions, the spatial specialization and growth differentials of major economic sectors in a sub-region of the parent region can be identified. The meanings and interpretations of equations (1) - (3) are summarized in table 2. Please note that the method has been extended in this study in two points, 1) Both employment and total output are used as indicators to measure the economic structure change; 2) the average (time t and t-1) rather than the status (time t) of the industrial mixture was measured. For more technical details, please refer to Stevens and Moore (1980), Bartels et al. (1982), and Knudeson (2000).

*Data source and level of aggregation*

The primary data source of this study is based on 528-sector input-output tables of the years of 1990, 1994, and 1999. These tables record the transactions among economic sectors of the economy of the Austin MSA in monetary terms. IO tables are obtained from Minnesota IMPLAN Group Incorporated (MIG) who compiles IO tables from a wide variety of sources including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor, and the U.S. Census Bureau (MIG 2004).

The regional economy is assumed to be composed of three segments[3], Information, Energy, and Others. The classification is primarily based on North American Industrial Classification System (NAICS) released by the U.S. department of Commerce (USDOC 2004), but some related literature were also referred (Machlup 1962; Porat and Robin 1977; Dizard 1989, Machado 1994). The definitions of the three segments are listed in Appendix B.

*Implementation procedures*

The following steps have been taken to integrate IO analysis and shift-share analysis with GIS (Figure3).

1) Build geodatabase

ArcGIS 8.3, a piece of popular GIS software developed by ESRI, Inc., was used to create both spatial and attribute databases. Thirteen regions used by Texas Comptroller's Office were adopted as the enumeration units.

2) Construct IO models

On the basis of the 528 $\times$ 528 IO tables of the year 1990, 1994, and 1999, 3$\times$3 IO models were constructed for both the thirteen regions of Texas and the state of Texas using IMPLAN Pro 2.0, a software developed by MIG. The output and employment data for three economic segments were generated and converted into dbf format.

3) Implement extended shift-share analysis

The dbf files generated in step 2 were joined to the attribute tables of the base map of Texas regions. New items were added into the attribute tables to include shift-share indices shown in

[3] Segment is defined as a set of economic sectors in this study.

table 2. The values of these indices were calculated using several short VBA scripts written for this application.

4) Map the results

Following general principles of cartographic design, a series of maps were produced on the basis of analytic results.

## Results and Discussions

*Results based on general input-output account*

Changes of employment and output were presented to provide a general description of the economic transformation in the thirteen regions of Texas. Employment and output were used as two indicators of the evolution economic structure (Tables 3-4 Figures 4-5).

**1) Employment**

***Information Segment***. Employment of this segment had the fastest growth compared to the other two segments. Employment of Capital region increase was over 200 percent, followed by Coastal Bend (97 percent) and Metroplex (79%). West Texas was the only lagging region, losing 27 percent of employment in this segment.

***Production Segment***. Twelve out of thirteen regions experienced some degree of growth. Capital, South Border, and Gulf Coast were the top three regions. Upper Rio Grande became the only regions that had a net loss of production employment.

***Energy Segment***. The change employment in energy segment showed a more complicated pattern. First, the employment declined in five regions. The growth in the remaining regions was much slower than in the other two segments. Golf Coast region led with an approximate 37 percent increase, followed by Alamo (32 percent) and Metroplex (31 percent).

**2) Output**

***Information Segment***. Just like employment, output of information segment grew faster than the other two segments. Capital region led the race with a growth rate of 277 percent, followed by and Metroplex (162 percent), and Alamo (115 percent). Even West Texas had a five percent increase despite the declining employment in this region.

***Production Segment***. Capital region led all the regions with a 134 percent increase. South Border and Metroplex ranked second and third respectively. Upper Rio Grande, with a net loss of production employment, experienced seven percent decrease in production output.

***Energy Segment***. Alamo and Central were the only regions that had a two digit increase in energy output. Seven regions suffered from the absolute decrease of output. Upper Rio Grande had the most severe loss of 76 percent, Northwest and Southeast also lost about one third of output during the 1990s.

*Trends based on direct effect*

Tables 5-17 present the change of elements of A matrix, the input compositions of economic segments to generate output. The general trends are, 1) the production segment: the direct input from the energy segment decreased significantly in all thirteen regions, the direct input from the information segment increased substantially in all thirteen regions except West Texas, both increase and decrease of the direct input from the production segment were observed, but the changes were much insignificant compared to those of the other two segments, 2) the energy segment: the direct input from the energy segment decreased significantly in all thirteen regions, the direct input from the information segment increased substantially in all thirteen regions, the direct input from the production segment increased in twelve regions except for Gulf Coast, but the rate of change were much lower than that of the information segment, 3) the information segment: the direct input from the energy segment decreased significantly in all thirteen regions, the direct input from the information segment increased substantially in all thirteen regions, the direct input from the production segment decreased in all thirteen regions. According to the above observations, it is not unreasonable to conclude that the manufacturing process of Texas economy was less dependent on production and energy segments, but was more dependent on the information segment.

*Results based shift-share analysis*

The results of the analysis are presented for the 1990-1999 period, as well as the two sub-periods: One of the most significant advantages of using GIS-based analysis is that both tables and maps are available to examine the spatial differentiation of economic transformation in the thirteen regions of Texas during the 1990s. Share-share analysis has been applied on both employment and output for the three segment (Information, energy, and others) at three time periods (1990-1994, 1994-1999 and 1990-1999) the results are presented according to the sequence of indicator (employment and output ), time period and economic segments to avoid confusion.

**1) Employment**

***Information Segment***. During the entire study period (1990 to 1999), two regions, Capital and Metroplex were found to be specialized in information segment, indicating the possible relationship between information employment and two metropolitan areas of Texas, Austin-San Marcos and Dallas-Fort worth. While Capital was the only high dependence/lead region; Metroplex lagged in the growth of information segment despite its specialization in the segment. Alamo evolved from high dependence/lead to low dependence/region. High Plain retreated from high dependence/lag to low dependence/lag. Golf Coast shifted from a low dependence/lead region to a low dependence/lag. Northwest and Upper Rio Grande remained to be high dependence/lag regions, meaning that these two regions specialized in information, but had a low growth rate of information employment (Figure 6, table 18).

***Energy Segment***. In 1990, there were two high dependence/lead regions (High Plain and West Texas), two high dependence/lag regions (Alamo and Metroplex), two low dependence/lead regions (Northwest, and Golf Coast), and six low dependence/lag regions (Capital, Central, Coastal Bend, southeast, Upper east, and Upper Rio Grande). In 1999, Northwest and Golf Coast joined High Plain and West Texas to become high dependence/lead regions. The other regions remained their status of 1990 (Figure 7, Table 19).

***Production Segment***. Production segment accounts for over 95 percent of the total economic sectors in a input-output table. It is natural that most of the regions specialized in this segment. The spatial pattern of production was pretty stable during the 1990s except for some adjustments. High Plain and Alamo regions advanced from low dependence/lag into high dependence/lead regions. However, Coastal Bend retreated into. During the 1990s, Capital was the only high dependence/lag region; Metroplex was the only low dependence/lag region in Texas. West Texas and Golf Coast remained to be high dependence/lag regions (Figure 8, Table 20).

### Output

***Information Segment***. The clustering of Information segment was clear on the fact that Capital region was the only high dependence/lead region during the 1990s. Metroplex and Alamo were the other two regions that specialized in the segment with lagged growth of output. Northwest and West Texas were identified as low dependence/lead regions in the first half of the 1990s, but both retreated into low dependence/lag region in 1999. All the other regions remained unchanged as low dependence/lag, indicating that they neither produced a lot output from information nor took a lead in the growth of output (Figure 9, Table 21).

***Energy Segment***. The output of energy segment remained a very stable spatial pattern during the 1990s. In 1990, there were four high dependence/lead regions (High Plain, Northwest, West Texas, and Gulf Coast); there were three low dependence/lag regions (Alamo, Metroplex, and Upper Rio Grande); and six low dependence/lead regions (Coastal bend, Central, South Bend, Southeast, South Border, and Upper East). In 1999, the only difference was that Upper Rio Grande became high dependence/lead region (Figure 10, Table 22).

***Production Segment***. In 1990, High Plain and Upper Rio Grande were identified as high dependence/lead region; West Texas, Northwest and Golf Coast were labeled as high dependence/lag region; the rest eight regions belonged to low dependence/lead region. In 1999, Upper Rio Grande retreated to be low dependence/lead region. The pattern of the rest 12 regions remain unchanged (Figure 11, Table 23).

## Conclusions and Future Research

This paper attempted to model the economic structure change through a new analytic framework based on the integration of GIS, input-output analysis and extended shift-share analysis in economically dynamic Texas. Extended shift-share analysis and input IO analysis enrich GIS users' toolbox to perform more sophisticated economic modeling and analysis. GIS, on the other hand, serves not only as an ideal database management tool (for both spatial and non-spatial data), but more importantly, offers technical platform for the full implementation of extended shift-share analysis and for automatic mapping and results presentation of both extended shift-share analysis and IO analysis.

**Based upon the empirical results, this paper has reached the following conclusions:** 1) information activities have grown considerably during the 1990s throughout Texas, 2) the information segment became less dependent on the inputs from the production and energy segments, 3) the production and energy segments became more dependent on the inputs from the information segment, 4) the digital economy emerged in Texas during the 1990s.

The argument that the U.S. economy has experienced a marked informatization process (Machado and Miller 1997) was supported by the results of this empirical study. The conclusions of this study are also generally consistent with the arguments and findings of several previous studies related to the measurement of information economy (Machlup 1962, Bell 1973, Porat and Robin 1977). In addition, the efforts of the state of Texas to develop an "information age economy" initiated in the 1980s (Williams 1988) have been proved to be effective according to the experience of the thirteen regions during the 1990s.

The information activities were becoming increasingly important in the Texas economy. The manufacturing processes became less energy and material intensive and more information intensive. However, it may be premature to declare that the digital economy is more environmentally friendly than industrial economy. Further investigations at various geographic scales are necessary to obtain more insights about the environmental consequences of the emerging digital economy and information age.

The period of 1990s also witnessed clear spatial specialization and differential growth in Texas. Five regions in the central part of Texas grew substantially in terms of both employment and output. They were Northwest, Metroplex, Capital, South order and Gulf Coast. Metroplex and Gulf Coast, with the help of two metropolitan areas, Dallas-Fort Worth and Houston, continued to dominate the Texas economy by contributing over 50 percent of total employment and gross regional output (GRP) to the state. However, these two regions remained to specialize in traditional industries such as oil business. Capital region, the home of the rising Silicon Hills was undoubtedly the superstar region during the 1990s. It dominated the development of information segment and doubled its total GRP in a short period of ten years. South Border region also experienced significant growth in total employment. However the productivity of the region did not increase proportionally.

Texas' strategy to develop information economy has played, and will continue to play an important role in the development of the state, especially in the context of the emerging digital economy and information age in the new millennium. However, the more concentrated development pattern and segment specialization also challenge the policy makers to plan a more balanced development in the state (Table 1, Figure 12).

Although we are excited by the preliminary results of this study, a few caveats about this study are also due.

First, the authors are aware of the sensitivity issues related to IO analysis. We admit the analysis based on highly aggregated three-segment IO models may not be able to prove a complete picture about the real situation. IO models at various aggregation levels will offer more detailed information and thus more insights to the research questions asked.

Second, due to the well-known difficulties in finding a uniform conversion unit by using physical units in IO tables, monetary units are adopted in all the analysis of this study. One potential problem, however, is that the change caused by the price fluctuation has been neglected. That is to say, the question like "to what extent the price factor influence the share of segments in the economy" remained unanswered in this study.

Third, the earliest exploration to the relationship between information and energy was initiated in the field of physics in the late 19$^{th}$ century (Leff and Rex, 1990). Some recent studies continued to examine the relationship between energy use and information activities from the perspective of macroeconomics (Spreng 1993, Chen, 1994, Machado and Miller 1997). Along this line, this study supplies more empirical evidences to the substitution effect between information and material/energy. The findings of these studies suggest another interesting research topic – the environmental impacts of the digital economy and information age. If the argument that the digital economy is fundamentally based on information (bits) rather than materials (atoms), will it be more environmentally friendly than the material (atoms) based industrial economy? Will the 3D hypothesis of the digital economy (dematerialization, decarbonization, and demobilization) be valid? These problems surely deserve separate investigations in the future.

**Acknowledgement:** This research was partially funded by the Technology for Sustainable Environment (TSE) program from the National Science Foundation and the AT&T faculty fellowship program. The opinions expressed in this paper are those of the authors and they do not necessarily reflect those of the funding agency.

**Table 1. 13 Texas's Comptroller's Regions**

| Region | Key industries in 2000 | Share of Texas' employment and GRP% (1970) | Share of Texas' employment and GRP % (2000) |
|---|---|---|---|
| Alamo | 1) Footwear, Except Rubber and Plastic,<br>2) Hydraulic Cement,<br>3) Miscellaneous Electrical Equipment | 8.8/8.1 | 8.5/7.8 |
| Capital | 1) Special Industry Machinery,<br>2) Electronic Components and Accessories,<br>3) Jewelry, Silverware and Plated Ware | 4.1/3.5 | 7.5/7.5 |
| Central | 1) Wood Buildings and Mobile Homes,<br>2) Primary Nonferrous Smelting and Refining,<br>3) Coal Mining | 5.1/4.1 | 4.4/3.6 |
| Coastal Bend | 1) Petroleum Refining,<br>2) Oil and Gas Field Services,<br>3) Industrial Chemicals | 4.7/4.7 | 3.2/2.8 |
| Golf Coast | 1) Crude Petroleum, Natural Gas and Gas Liquids,<br>2) Oil and Gas Field Services,<br>3) Petroleum Refining | 21.1/24.9 | 23.7/26.4 |
| High Plain | 1) Ordnance and Ammunition,<br>2) Oil and Gas Field Services,<br>3) Crude Petroleum, Natural Gas and Gas Liquids | 6.2/5.4 | 3.8/3.3 |
| Metroplex | 1) Crude Petroleum, Natural Gas and Gas Liquids,<br>2) Communications Equipment,<br>3) Aerospace | 25.5./25.8 | 29.5/31.9 |
| Northwest | 1) Oil and Gas Field Services,<br>2) Crude Petroleum, Natural Gas and Gas Liquids,<br>3) Wood Buildings and Mobile Homes | 4.6/3.9 | 2.6/2.1 |
| South Border | 1) Miscellaneous Transportation Services,<br>2) Apparel,<br>3) Health Services | 3.5/2.8 | 6.7/3.4 |
| South East | 1) Petroleum Refining,<br>2) Plastics Materials and Synthetics,<br>3) Logging | 4.2/4.5 | 2.9/2.7 |
| Upper East | 1) Railroad Equipment,<br>2) Coal Mining,<br>3) Tires and Inner Tubes | 5.3/4.5 | 4.4/3.9 |
| Upper Rio Grande | 1) Footwear, Except Rubber and Plastic,<br>2) Primary Nonferrous Smelting and Refining,<br>3) Apparel | 3.1/2.9 | 2.8/2.5 |
| West Texas | 1) Ordnance and Ammunition,<br>2) Oil and Gas Field Services, Crude Petroleum,<br>3) Natural Gas and Gas Liquids | 3.7/4.8 | 2.5/2.4 |

Source: Compiled by author from Texas Comptroller of Public Accounts

## Table 2. Interpretations of the extended shift-share analysis

| | $[(P_{ij} - P_{nj}) - (P_{in} - P_{nN})] > 0$ | $[(P_{ij} - P_{nj}) - (P_{in} - P_{nN})] < 0$ |
|---|---|---|
| $[(E_{ij} - E_{ij}^H)(t-1) + (E_{ij} - E_{ij}^H)(t)]/2 > 0$ | High dependence/lead area: compared to state average, the growth of region j is more dependent on sector i and sector i has a faster growth rate | High dependence/lead area: compared to state average, the growth of region j is more dependent on sector i and sector i has a slower growth rate |
| $[(E_{ij} - E_{ij}^H)(t-1) + (E_{ij} - E_{ij}^H)(t)]/2 < 0$ | High dependence/lag area: compared to state average, the growth of region j is more dependent on sector i and sector i has a slower growth rate | High dependence/lead area: compared to state average, the growth of region j is less dependent on sector i and sector i has a slower growth rate |

## Table 3.[4] Segment employment change in thirteen Texas regions 1990 - 1999

| Region | Production | Energy | Information |
|---|---|---|---|
| Alamo | 40.54% | 32.44% | 61.16% |
| Capital | 64.36% | -23.03% | 214.97% |
| Central | 34.10% | -2.25% | 52.26% |
| Coastal Bend | 27.60% | -16.84% | 97.25% |
| Gulf Coast | 42.20% | 36.89% | 54.40% |
| High Plains | 11.71% | 13.11% | 42.07% |
| Metroplex | 42.27% | 30.80% | 79.41% |
| Northwest | 11.27% | 3.87% | 61.49% |
| Southeast | 27.23% | -42.45% | 35.59% |
| South Border | 43.77% | 1.65% | 25.42% |
| Upper East | 30.18% | 3.83% | 52.00% |
| Upper Rio Grande | -17.19% | -78.72% | 59.28% |
| West Texas | 11.01% | 23.15% | -26.96% |

[4] All the data are original unless indicated otherwise.

**Table 4. Segment Output change in Thirteen Texas Regions 1990 - 1999**

| Region | Manufacturing | Energy | Information |
|---|---|---|---|
| Alamo | 55.90% | 51.61% | 115.08% |
| Capital | 134.85% | -3.99% | 277.17% |
| Central | 48.38% | 38.28% | 62.41% |
| Coastal Bend | 38.10% | -28.92% | 97.49% |
| Gulf Coast | 58.86% | 5.98% | 101.79% |
| High Plains | 29.13% | -20.34% | 68.08% |
| Metroplex | 74.19% | 0.67% | 162.07% |
| Northwest | 15.64% | -35.09% | 67.52% |
| Southeast | 16.57% | -34.89% | 46.95% |
| South Border | 90.80% | 8.89% | 101.23% |
| Upper East | 36.05% | 2.70% | 85.87% |
| Upper Rio Grande | -7.07% | -76.67% | 39.11% |
| West Texas | 21.90% | -22.70% | 5.29% |

**TABLE 5. PERCENTAGE CHANGE OF A MATRIX ELEMENTS, ALAMO, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 0% | 16% | -14% |
| Energy | -34% | -21% | -41% |
| Information | 43% | 61% | 38% |

**Table 6. Percentage change of A matrix elements, Capital, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 3% | 58% | -19% |
| Energy | -61% | -37% | -72% |
| Information | 81% | 167% | 59% |

**Table 7. Percentage change of A matrix elements, Coastal Bend, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 1% | 21% | -12% |
| Energy | -45% | -27% | -56% |
| Information | 38% | 63% | 29% |

**Table 8. Percentage change of A matrix elements, Central, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 5% | 64% | -8% |
| Energy | -62% | -41% | -63% |
| Information | 35% | 107% | 28% |

**Table 9. Percentage change of A matrix elements, Golf Coast, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | -1% | -13% | -11% |
| Energy | -29% | 25% | -67% |
| Information | 36% | 16% | 27% |

**Table 10. Percentage change of A matrix elements, High Plain, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | -1% | 4% | -14% |
| Energy | -28% | -9% | -45% |
| Information | 44% | 47% | 34% |

**Table 11. Percentage change of A matrix elements, High Plain, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | -1% | 13% | -14% |
| Energy | -45% | -31% | -55% |
| Information | 37% | 52% | 29% |

**TABLE 12. PERCENTAGE CHANGE OF A MATRIX ELEMENTS, NORTH WEST, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 0% | 6% | -12% |
| Energy | -41% | -18% | -54% |
| Information | 45% | 50% | 37% |

**Table 13. Percentage change of A matrix elements, South Border, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 3% | 28% | -1% |
| Energy | -43% | -26% | -47% |
| Information | 3% | 24% | 6% |

**Table 14. Percentage change of A matrix elements, South East, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 7% | 59% | -2% |
| Energy | -54% | -28% | -59% |
| Information | 16% | 69% | 12% |

**Table 15. Percentage change of A matrix elements, Upper East , 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 1% | 27% | -13% |
| Energy | -48% | -37% | -52% |
| Information | 46% | 79% | 36% |

**Table 16. Percentage change of A matrix elements, Upper Rio Grande, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 5% | 56% | -11% |
| Energy | -53% | -28% | -61% |
| Information | 42% | 108% | 29% |

**Table 17. Percentage change of A matrix elements, West Texas, 1990-1999**

| | Production | Energy | Information |
|---|---|---|---|
| Production | 11% | 15% | -2% |
| Energy | -79% | -42% | -84% |
| Information | -45% | -68% | 24% |

**Table 18. Shift-share Results: Information Segment (Employment)**

| Period | 90-94 | | | 94-99 | | | 90-99 | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | ?E | ?P | Type | ?E | ?P | Type | ?E | ?P | Type |
| Alamo | + | + | ++ | - | - | -- | - | - | -- |
| Capital | + | + | ++ | + | + | ++ | + | + | ++ |
| Central | - | - | -- | - | + | -+ | - | - | -- |
| Coastal Bend | - | - | -- | - | - | -- | - | - | -- |
| Gulf Coast | + | - | +- | - | - | -- | - | - | -- |
| High Plains | - | + | -+ | - | - | -- | - | - | -- |
| Metroplex | + | - | +- | + | - | +- | + | - | +- |
| Northwest | - | + | -+ | - | - | -- | - | + | -+ |
| South Border | - | - | -- | - | - | -- | - | - | -- |
| Southeast | - | - | -- | - | - | -- | - | - | -- |
| Upper East | - | - | -- | - | - | -- | - | - | -- |
| Upper Rio Grande | - | + | -+ | - | + | -+ | - | + | -+ |
| West Texas | - | - | -- | - | - | -- | - | - | -- |

?E: + High dependence; -: Low dependence

?P : + Lead; -: Lag

Type: ++ High dependence/Lead; --: Low dependence/Lag

**Table 19. Shift-share Results: Energy Segment (Employment)**

| Period | 90-94 | | | 94-99 | | | 90-99 | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | ?E | ?P | Type | ?E | ?P | Type | ?E | ?P | Type |
| Alamo | - | + | -+ | - | - | -- | - | + | -+ |
| Capital | - | - | -- | - | - | -- | - | - | -- |
| Central | - | - | -- | - | - | -- | - | - | -- |
| Coastal Bend | - | - | -- | - | - | -- | - | - | -- |
| Gulf Coast | + | - | +- | + | + | ++ | + | + | ++ |
| High Plains | + | + | ++ | + | - | +- | + | + | ++ |
| Metroplex | - | + | -+ | - | - | -- | - | + | -+ |
| Northwest | + | - | +- | + | + | ++ | + | + | ++ |
| South Border | - | - | -- | - | - | -- | - | - | -- |
| Southeast | - | - | -- | - | - | -- | - | - | -- |
| Upper East | + | - | +- | - | + | -+ | + | - | +- |
| Upper Rio Grande | - | - | -- | - | + | -+ | - | - | -- |
| West Texas | + | + | ++ | + | + | ++ | + | + | ++ |

?E: + High dependence; -: Low dependence
?P : + Lead; -: Lag
Type: ++ High dependence/Lead; --: Low dependence/Lag

**Table 20. Shift-share Results: Production Segment (Employment)**

| Period | 90-94 | | | 94-99 | | | 90-99 | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | ?E | ?P | Type | ?E | ?P | Type | ?E | ?P | Type |
| Alamo | + | - | +- | + | + | ++ | + | + | ++ |
| Capital | + | - | +- | - | - | -- | - | - | -- |
| Central | + | + | ++ | + | + | ++ | + | + | ++ |
| Coastal Bend | + | + | ++ | - | - | -- | - | - | -- |
| Gulf Coast | - | + | -+ | - | - | -- | - | + | -+ |
| High Plains | + | - | +- | + | + | ++ | + | + | ++ |
| Metroplex | - | - | -- | - | - | -- | - | - | -- |
| Northwest | + | + | ++ | + | + | ++ | + | + | ++ |
| South Border | + | + | ++ | + | + | ++ | + | + | ++ |
| Southeast | + | + | ++ | + | + | ++ | + | + | ++ |
| Upper East | + | + | ++ | + | + | ++ | + | + | ++ |
| Upper Rio Grande | + | + | ++ | + | - | +- | + | + | ++ |
| West Texas | - | + | -+ | - | + | -+ | - | + | -+ |

?E: + High dependence; -: Low dependence
?P : + Lead; -: Lag
Type: ++ High dependence/Lead; --: Low dependence/Lag

**Table 21. Shift-share Results: Information Segment (Output)**

| Period | 90-94 | | | 94-99 | | | 90-99 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Region** | **? E** | **? P** | **Type** | **? E** | **? P** | **Type** | **? E** | **? P** | **Type** |
| **Alamo** | + | - | **+-** | + | - | **+-** | + | - | **+-** |
| **Capital** | + | + | **++** | + | + | **++** | + | + | **++** |
| **Central** | - | - | **--** | - | - | **--** | - | - | **--** |
| **Coastal Bend** | - | - | **--** | - | + | **-+** | - | - | **--** |
| **Gulf Coast** | - | + | **-+** | - | - | **--** | - | - | **--** |
| **High Plains** | - | - | **--** | - | - | **--** | - | - | **--** |
| **Metroplex** | + | - | **+-** | + | + | **++** | + | + | **++** |
| **Northwest** | - | + | **-+** | - | - | **--** | - | - | **--** |
| **South Border** | - | - | **--** | - | - | **--** | - | - | **--** |
| **Southeast** | - | - | **--** | - | - | **--** | - | - | **--** |
| **Upper East** | - | - | **--** | - | - | **--** | - | - | **--** |
| **Upper Rio Grande** | - | - | **--** | - | + | **-+** | - | - | **--** |
| **West Texas** | - | + | **-+** | - | - | **--** | - | - | **--** |

? E: + High dependence; -: Low dependence
? P : + Lead; -: Lag
Type: ++ High dependence/Lead; --: Low dependence/Lag

**Table 22. Shift-share Results: Energy Segment (Output)**

| Period | 90-94 | | | 94-99 | | | 90-99 | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | ?E | ?P | Type | ?E | ?P | Type | ?E | ?P | Type |
| Alamo | - | + | -+ | - | + | -+ | - | + | -+ |
| Capital | - | - | -- | - | - | -- | - | - | -- |
| Central | - | + | -+ | - | - | -- | - | + | -+ |
| Coastal Bend | - | + | -+ | - | - | -- | - | + | -+ |
| Gulf Coast | + | + | ++ | + | + | ++ | + | + | ++ |
| High Plains | + | + | ++ | + | + | ++ | + | + | ++ |
| Metroplex | - | - | -- | - | - | -- | - | - | -- |
| Northwest | + | + | ++ | + | + | ++ | + | + | ++ |
| South Border | - | + | -+ | - | - | -- | - | + | -+ |
| Southeast | - | + | -+ | - | - | -- | - | + | -+ |
| Upper East | - | + | -+ | + | + | ++ | - | + | -+ |
| Upper Rio Grande | - | + | -- | - | + | -+ | - | + | -+ |
| West Texas | + | + | ++ | + | - | +- | + | + | ++ |

?E: + High dependence; -: Low dependence
?P : + Lead; -: Lag
Type: ++ High dependence/Lead; --: Low dependence/Lag

**Table 23. Shift-share Results: Production Segment (Employment)**

| **Period** | **90-94** | | | **94-99** | | | **90-99** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Region** | **? E** | **? P** | **Type** | **? E** | **? P** | **Type** | **? E** | **? P** | **Type** |
| **Alamo** | + | - | +- | + | - | +- | + | - | +- |
| **Capital** | + | - | +- | + | + | ++ | + | - | +- |
| **Central** | + | - | +- | + | + | ++ | + | - | +- |
| **Coastal Bend** | + | - | +- | + | + | ++ | + | - | +- |
| **Gulf Coast** | - | + | -+ | - | - | -- | - | + | -+ |
| **High Plains** | + | + | ++ | + | + | ++ | + | + | ++ |
| **Metroplex** | + | - | +- | - | - | -- | + | - | +- |
| **Northwest** | - | + | -+ | - | + | -+ | - | + | -+ |
| **South Border** | + | - | +- | + | + | ++ | + | - | +- |
| **Southeast** | + | - | +- | + | + | ++ | + | - | +- |
| **Upper East** | + | - | +- | + | + | ++ | + | - | +- |
| **Upper Rio Grande** | + | + | ++ | + | - | +- | + | - | +- |
| **West Texas** | - | + | -+ | - | + | -+ | - | + | -+ |

? E: + High dependence; -: Low dependence
? P : + Leading; -: Lag
Type: ++ High dependence/Lead; --: Low dependence/Lag

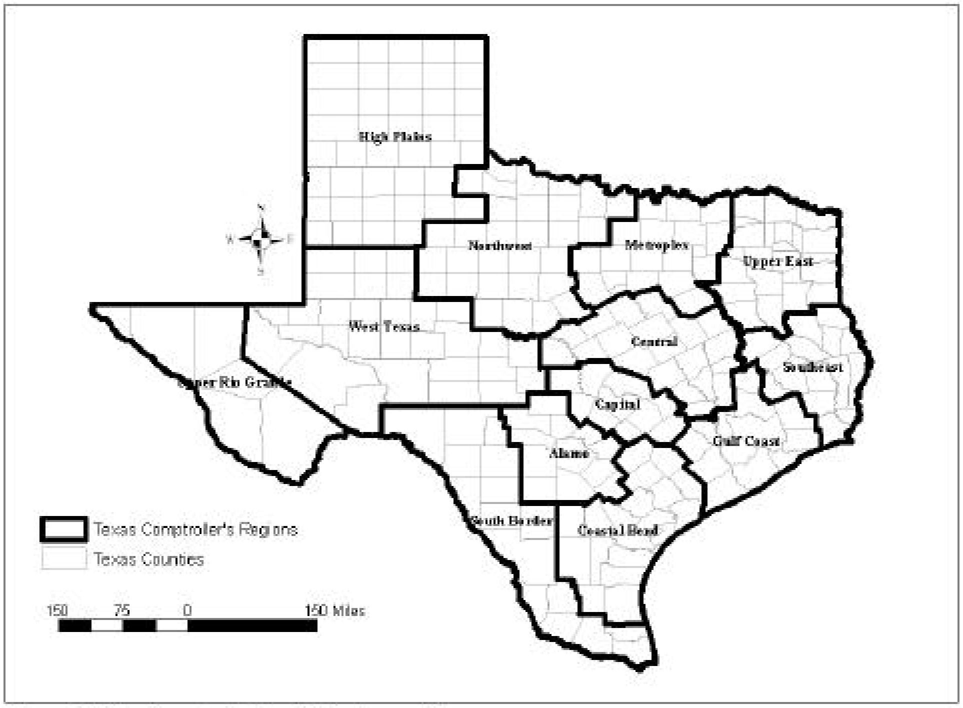


**Figure 1. The Comptroller's 13 Regions of Texas**
**Source: Texas Comptroller of Public Accounts**

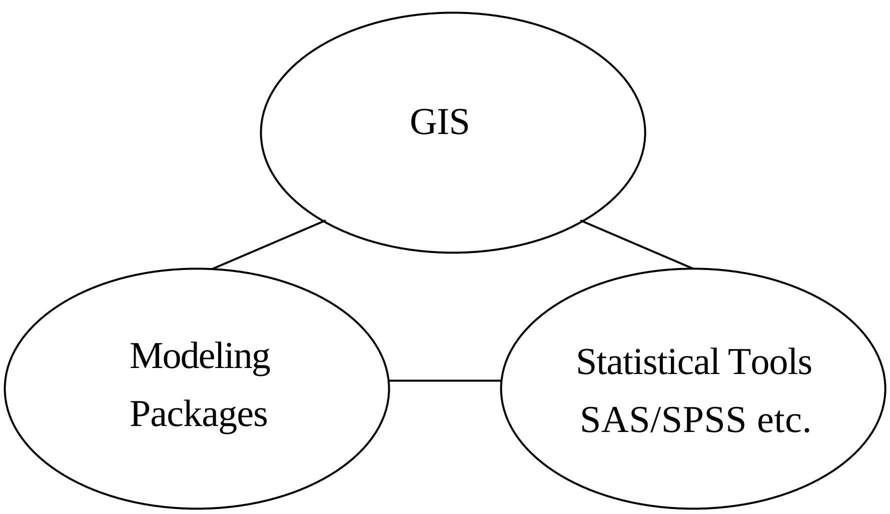


Figure 2. Loose coupling of GIS and other modeling tools

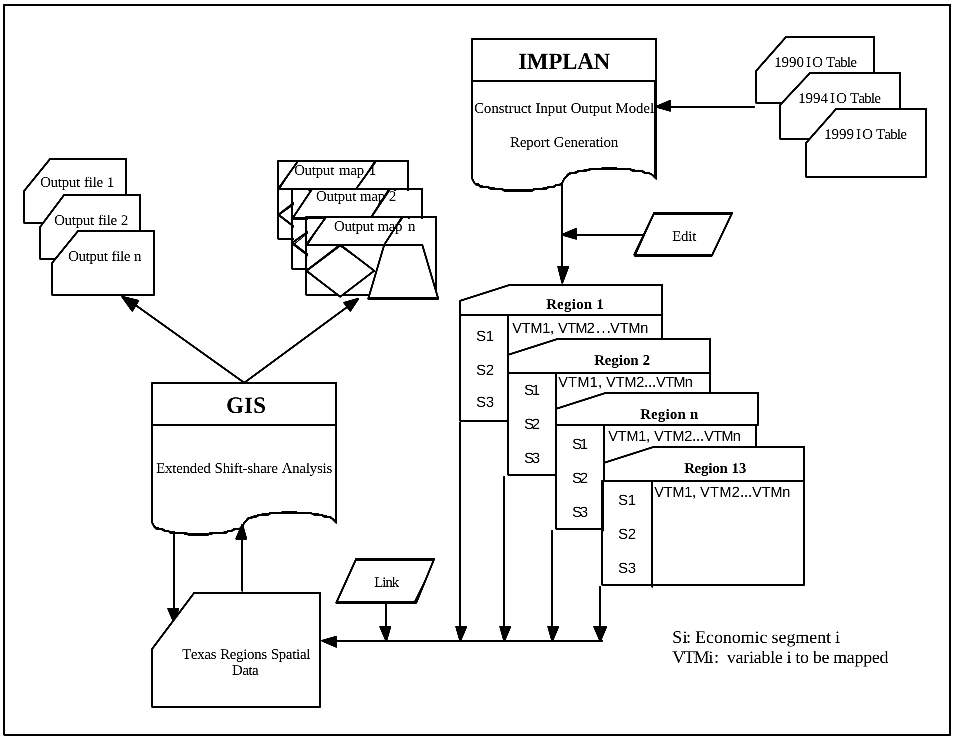


Figure 3. A loose couple model of GIS, IO analysis, and shift-share analysis.

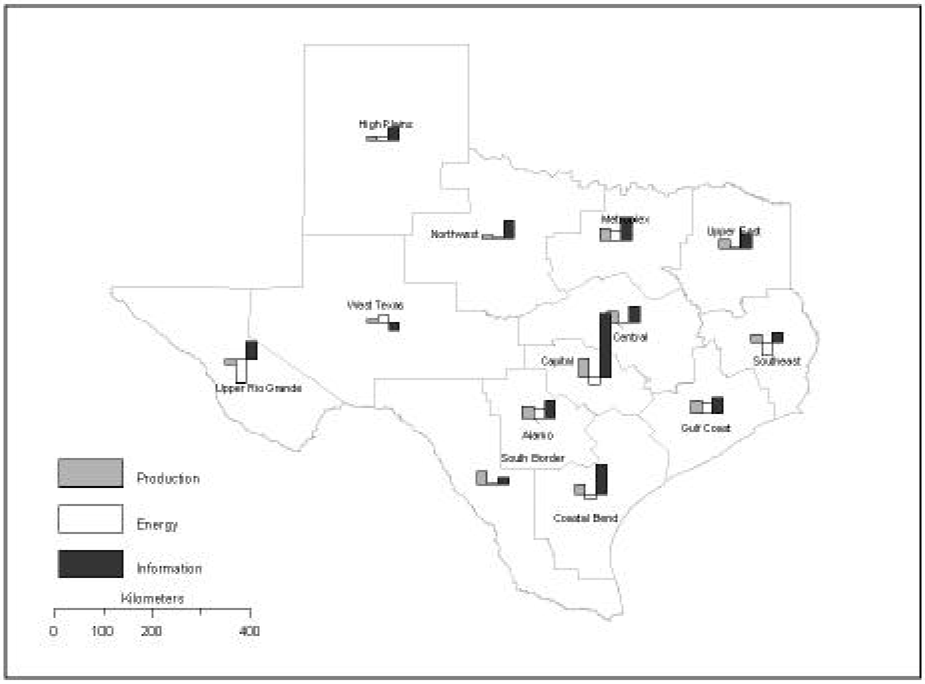


Figure 4. **Segment employment change in thirteen Texas regions 1990-1999**

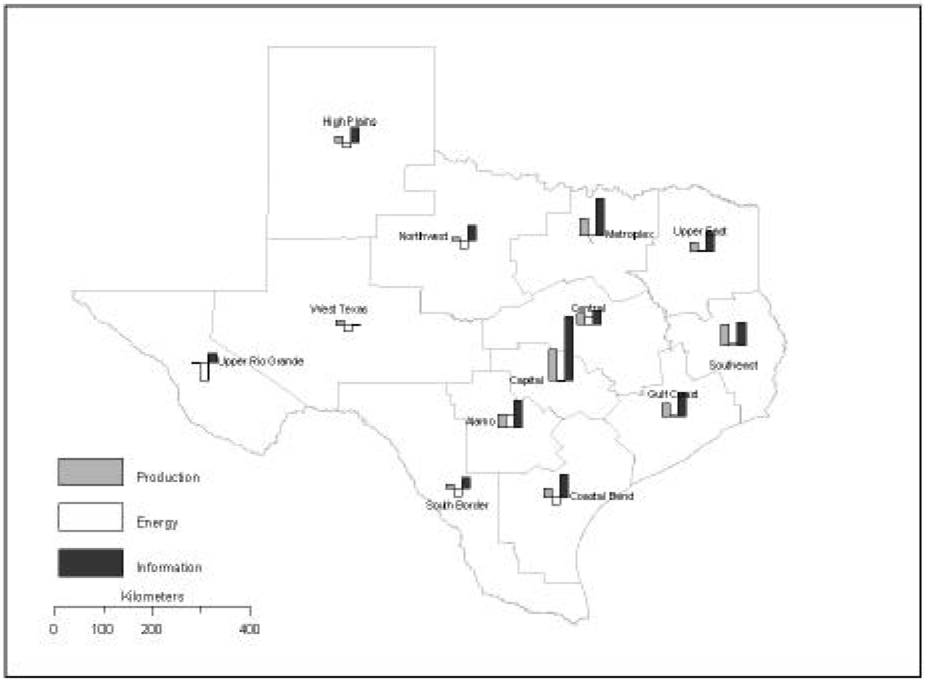


Figure 5. Segment output change in thirteen Texas regions 1990-1999

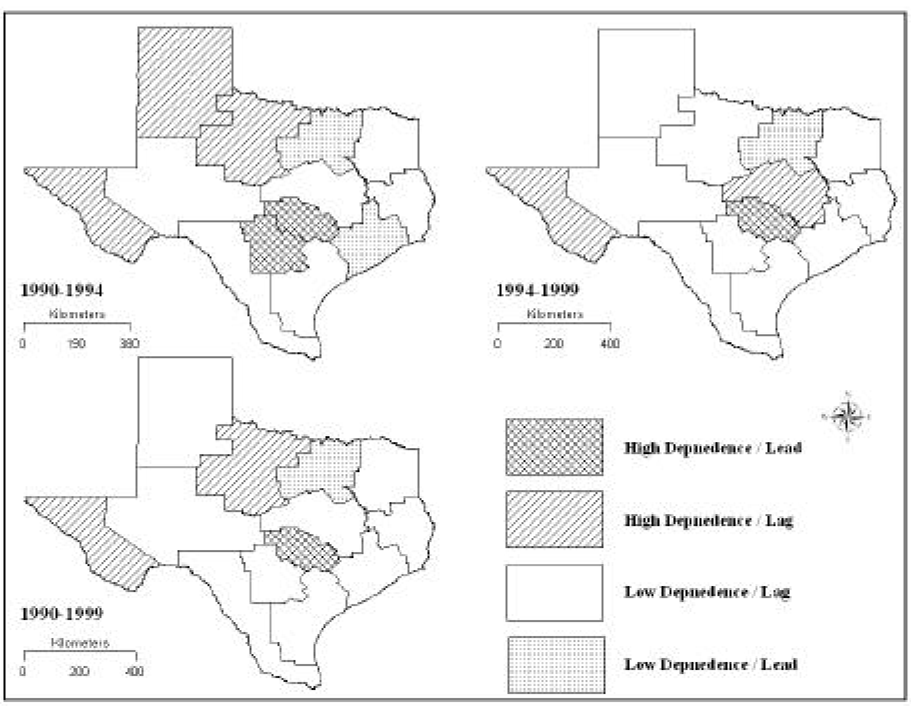


Figure 6. Spatial specialization and differential growth of information employment: 1990-1999

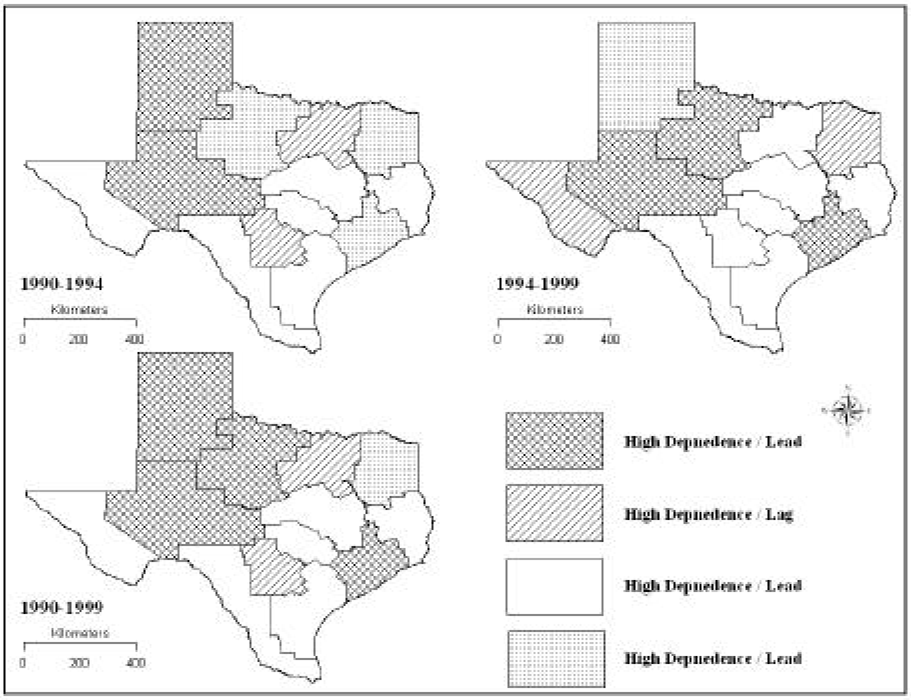


Figure 7. Spatial specialization and differential growth of energy employment: 1990-1999

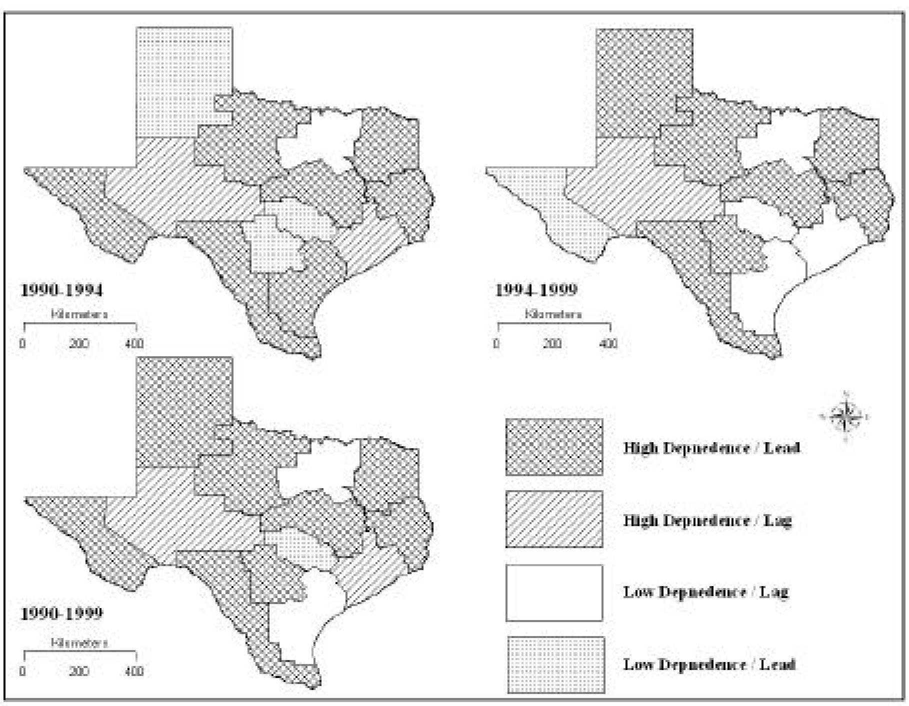


Figure 8. Spatial specialization and differential growth of production employment: 1990-1999

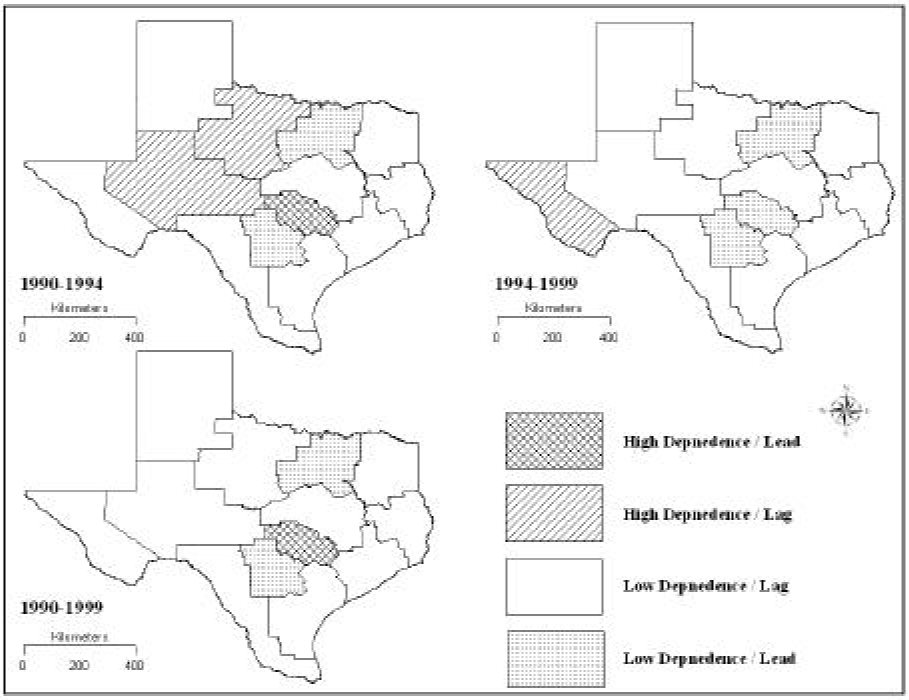


Figure 9. Spatial specialization and differential growth of information employment: 1990-1999

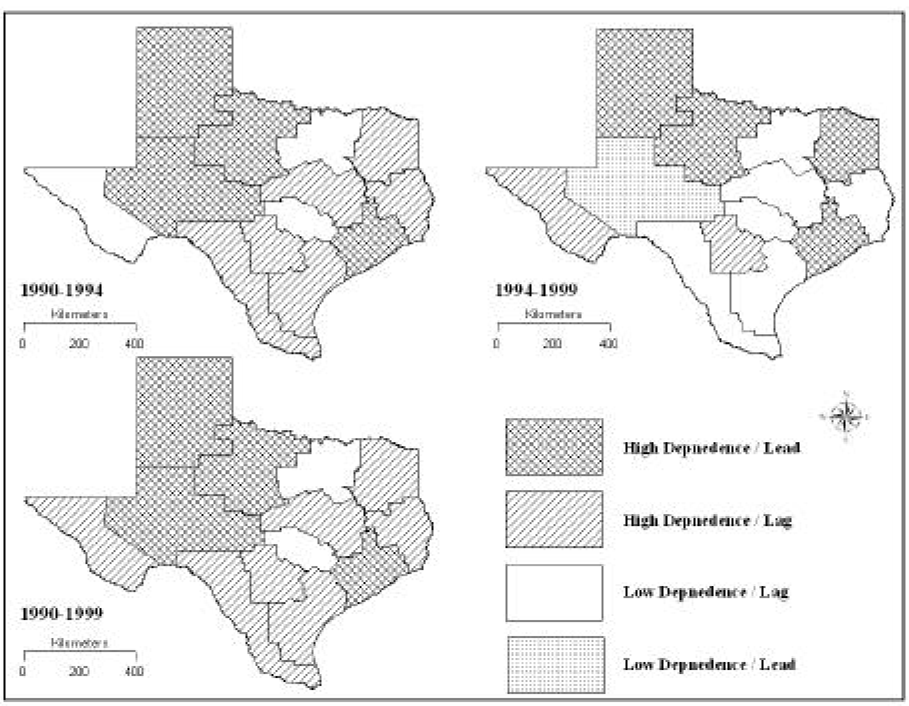


Figure 10. Spatial specialization and differential growth of energy employment: 1990-1999

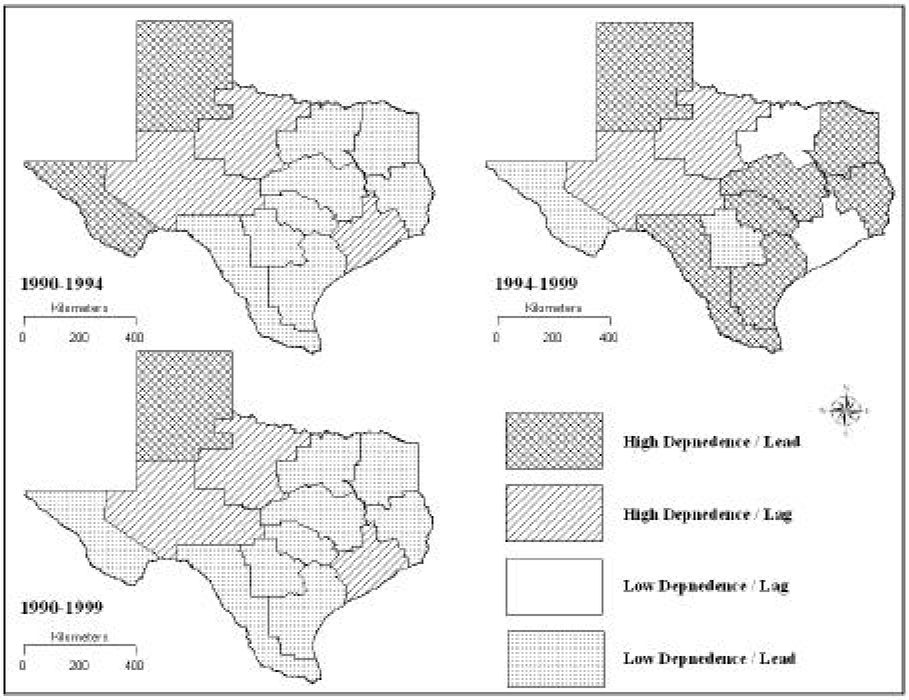


Figure 11. Spatial specialization and differential growth of production employment: 1990-1999

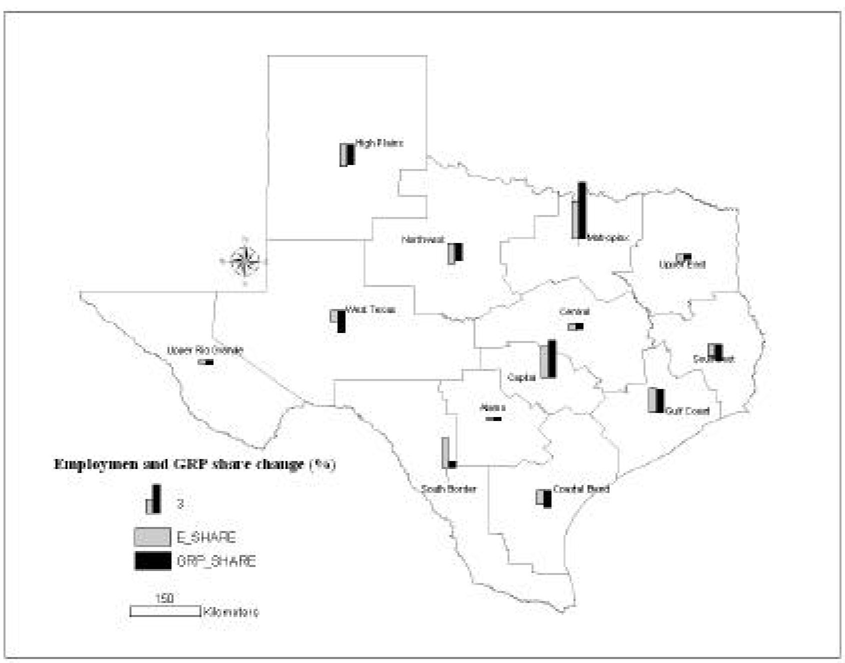


Figure 12. Employment and share change of Texas regions, 1990-1999

# Appendix A

### The explanation of symbols in equation (1) - (3)

$i$: Economic segment

$j$: Region

$n$: All economic segments

$N$: Parent region (State of Texas)

$E_{ij}$: Total employment or output in segment $i$ of region $j$

$P_{nN}$: Percentage change of total employment or output of all segments in the state

$P_{iN}$: Percentage change of total employment or output of segment $i$ in the state

$P_{nj}$: Percentage change of total employment or output of all the segments in region $j$

$P_{ij}$: Percentage change of total employment or output of segment $i$ in region $j$

$\Delta E_{ij}$: Change of employment or output of segment $i$ in region $j$ within a period of time

$SG_{ij}$: State growth effect; the part of $\Delta E_{ij}$ attributable to the growth of state effect

$SI_{ij}$: State economic mix effect; the part of $\Delta E_{ij}$ attributable to the difference of economic composition in region $j$ and that in the state

$RG_{ij}$: Regional growth effect; the part of $\Delta E_{ij}$ attributable to the growth of region $j$

$SI_{ij}$: Regional economic mix effect; the part of $\Delta E_{ij}$ attributable to the economic composition in region $j$

$E_{ij}^{H}$: Homothetic employment/output in sector Regional economic mix effect; the part of $\Delta E_{ij}$ attributable to the economic $i$ in region $j$, which is defined as the employment/output that sector $I$ would have if the structure of the employment/output in region $j$ were equal to the state structure.

# Appendix B

## Definition of economic segments

Table A1 Energy (8 sectors)

| IO table Record No. | Description | 87 SIC code | Note |
|---|---|---|---|
| 37 | COAL MINING | 1200 | |
| 38 | NATURAL GAS & CRUDE PETROLEUM | 1310 | |
| 39 | NATURAL GAS LIQUIDS | 1320 | |
| 213 | LUBRICATING OILS AND GREA SES | 2992 | |
| 443 | ELECTRIC SERVICES | 4910 | Also part of 4930 |
| 444 | GAS PRODUCTION AND DISTRIBUTIO | 4920 | Also part of 4930 |
| 511 | STATE AND LOCAL ELECTRIC UTILI | | Part of 4910 |
| 512 | OTHER STATE AND LOCAL GOVT ENT | -- | |

Table A2 ICT (17 sectors)

| IO table Record | Description | 87 SIC code |
|---|---|---|
| 267 | NONFERROUS WIRE DRAWING AND IN | 3357 |
| 339 | ELECTRONIC COMPUTERS | 3571 |
| 340 | COMPUTER STORAGE DEVICES | 3572 |
| 341 | COMPUTER TERMINALS | 3575 |
| 342 | COMPUTER PERIPHERAL EQUIPMENT, | 3577 |
| 343 | CALCULATING AND ACCOUNTING MAC | 3578 |
| 370 | RADIO AND TV RECEIVING SETS | 3651 |
| 372 | TELEPHONE AND TELEGRAPH APPARA | 3661 |
| 373 | RADIO AND TV COMMUNICATION EQU | 3663 |
| 374 | COMMUNICATIONS EQUIPMENT NEC | 3669 |
| 375 | ELECTRON TUBES | 3671 |
| 376 | PRINTED CIRCUIT BOARDS | 3672 |
| 377 | SEMICONDUCTORS AND RELATED DEV | 3674 |
| 378 | ELECTRONIC COMPONENTS, N.E.C. | 3675 3676 367 |
| 400 | SEARCH & NAVIGATION EQUIPMENT | 3812 |
| 402 | AUTOMATIC TEMPERATURE CONTROLS | 3822 |
| 473 | EQUIPMENT RENTAL AND LEASING | 7350 |

Table A3 Information (13 sectors)

| IO table Record | Description | 87 SIC code |
|---|---|---|
| 174 | NEWSPAPERS | 2710 |
| 175 | PERIODICALS | 2720 |
| 176 | BOOK PUBLISHING | 2731 |
| 178 | MISCELLANEOUS PUBLISHING | 2740 |
| 181 | GREETING CARD PUBLISHING | 2770 |
| 371 | PHONOGRAPH RECORDS AND TAPE | 3652 |
| 441 | COMMUNICATIONS, EXCEPT RADIO A | 4810 4820 4840 |
| 442 | RADIO AND TV BROADCASTING | 4830 |
| 470 | OTHER BUSINESS SERVICES | 7320 7331 733 |
| 475 | COMPUTER AND DATA PROCESSING S | 7370 |
| 483 | MOTION PICTURES | 7800 |
| 484 | THEATRICAL PRODUCERS, BANDS ET | 7920 |
| 497 | OTHER EDUCATIONAL SERVICES | 8230 8240 8290 |

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