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16. Abstract

This study undertook an economic impact exercise for all Texas ports, updated a similar study done a decade earlier, and so assisted TxDOT with incorporating the most recent marine port impacts into their state transportation planning. The study was awarded to a joint CTR-TTI team but work did not begin until the scope was clarified by TxDOT, following concerns expressed by some members of the Texas Ports Association (TPA). Almost all the larger Texas ports had undertaken economic impact studies and were understandably concerned about any new study providing different answers. This was highly likely as economic impact output is influenced by the timing, scale, and specifications of each study. Accordingly, it was agreed that where a Texas port had already completed an economic impact study, the results would be reported to TxDOT in this project. The work also provided both a forecast of container growth at Texas terminals and an estimate of the economic impact of Texas ports on the U.S economy.

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Chapter 1. Background and Introduction

1.1 Introduction

The U.S. economy has undergone profound changes in the past 20 years as real Gross Domestic Product increased from $4.9 to $13.2 trillion in 2006 (1). These changes not only altered the composition and size of the U.S. business sector, but also the nation's role in the global economy. The economy of Texas reflects this focus, benefiting both from the extensive border it shares with Mexico—thus dominating U.S.-Mexico NAFTA trade—and the post-2000 world export and import markets currently served by the Texas transportation system, especially its maritime sectors. Total U.S. exports for 2006 were $1.1 trillion and, for the fifth consecutive year, Texas was ranked the number one state by export revenue with some $151 billion originating in the state. Imports were even higher, influenced by energy and petroleum prices, reaching $245 billion moved by Texas seaports in 2006 (2). Texas sea ports therefore play an important role in both the state and national economies as the gateways for a wide variety of goods to many sectors of the U.S economy. Furthermore, smaller ports provide different services, not only in terms of goods movement, but also in providing a wide range of marine-based tourist activities that benefit many Texans.

In 2004 the Bureau of Transportation Statistics reported (3) the value of U.S. international merchandise trade by mode as water (39.4 percent), air (27.7 percent), truck (21.1 percent), rail (4.9 percent), pipeline (1.4 percent), and other/miscellaneous (6.5 percent). Clearly, marine ports are important in sustaining the modal split for global trade and this is unlikely to significantly change in the next decade. At present, four Texas deep-water ports rank in the top ten U.S. water ports by shipment weight. They are

- Houston (#2),
- Beaumont (#5),
- Corpus Christi (#6), and
- Texas City (#9).

The percentage increases in tonnage handled by these ports between 1991 and 2001 are

- Houston (41 percent),
- Beaumont (254 percent),
- Corpus Christi (31 percent), and
- Texas City (44 percent).

It is therefore vital to the TxDOT mission of promoting an effective state transportation system to include current and planned Texas port activities. This could include maintaining an accurate picture of port impacts on the state and regional economies and an ability to review the economic impacts of Texas port operations and investment programs.

1.2 Study Background

In 1996, TxDOT Research Report 7-2994, entitled "The Value of Texas Seaports" sought to quantify the cumulative benefits to the state economy derived from the Texas maritime industry (4). In describing the value of ports to the state economy, the researchers cited factors such as the importance of trade, the inherent efficiencies of maritime transport, and the necessity of supplying goods to a growing and geographically diverse population. In the decade since this report was published, all of these factors have grown even more salient:

- international trade is more integral to the Texas economy now than it was in the mid 1990s,
- the high price of oil, which has tripled since the mid 1990s, has made the energy efficiencies associated with maritime transport more compelling, and
- the Texas population has increased by 15 percent since the earlier study was performed, increasing the demand for all waterborne commodities.

Other factors that would have been largely unforeseen at the time of the report's writing include a dramatic increase in containerized imports from China and other developing Asian economies that has, at times, overwhelmed port capacity on the West Coast and led shippers to examine gateway alternatives, such as Texas ports for delivering goods to the U.S. interior. Terminals now have the potential to benefit from technological advances in cranes, stackers, and inventory systems and so become more productive and efficient. Safety and security have become important in the last decade and the advent of the Transportation Workers Identification Credential (TWIC) will require that port terminals adopt further approved technologies for ensuring staff entering port facilities meet safety and security requirements (5). Furthermore, legislation at the federal and state level has made it easier for ports to collaborate with Metropolitan Planning Organizations, rail companies, Departments of Transportation and key customers, like inland distribution centers. This has made the operations and economic vitality of ports more salient to the well being of all Texans, as these collaborations impact even those who live far from the coast.

The rapid growth of the U.S. cruise industry, which in 2003 grew by 11 percent, has also benefited Texas and will become a more significant element of Texas port operations when the new Houston Bayport terminal opens in 2008. Finally, Texas ports have become critical in sustaining military operations. In the past 2 years, 40 percent of all military equipment moving through U.S. seaports to the Middle East passed through Texas.

The increasing value of maritime commerce to the American economy has resulted in the necessary resources for maintaining access channels and other port infrastructure. Furthermore, as ports have become more congested and extended their hours of operations, the logistics of maintaining ports have become more complicated. Yet, the true cost of deferring maintenance is often not realized until the cost of corrective actions becomes high. While Texas has been working to expand its port capacity, other states have been making similar investments in the hope of gaining market share in global and interstate commerce. The emergence of mega-containerships, the consolidation of shipping lines, and the growing size of distribution centers have all been positive developments for commerce. However, these developments have simultaneously made ports more vulnerable to sudden changes in business if they allow their infrastructure to stagnate.

1.3 Study 0-5538: Proposal Modification

Collectively, these issues stimulated TxDOT to update through its Research Technology and Implementation (RTI) Division the earlier 7-2994 Research Report and to address all Texas port impacts, including those smaller ports that lacked resources to commission their own economic impact studies. In addition, state and federal interest in containerization—stimulated perhaps by the 2004 difficulties at the southern Californian terminals, which created severe congestion and consequent delays to U.S. and Texas shippers—led the Department to specifically request the examination of container operations in greater detail. The study was awarded in 2005 (6) to a joint University team from the Center for Transportation Research (CTR) at The University of Texas at Austin and the Texas Transportation Institute (TTI) at Texas A&M University at College Station.

The CTR-TTI study work plan proposed to estimate the economic impacts of Texas ports using input-output modeling. The core of an input-output model is data tables that describe the transaction flows among the various sectors of the economy, where the *output* of one sector can provide *input* to another. These tables allow the model to trace the *direct* and *indirect effects* of an increase in demand for a given commodity or service. Input-output models also allow for the estimation of *induced effects* that arise from direct and indirect effects—the idea is that gains in employment will translate to gains in household income, which, by boosting consumer demand, will further stimulate the economy. As an example, a study of the economic impacts of the port of Corpus Christi estimated a gain to Texas of about 39,000 jobs. Of these, about 11,000 were generated directly, 9,000 indirectly, and another 19,000 were induced employment. Other measures of economic impacts common in input-output analysis are changes in output and tax revenues.

In addition, the geographic level of the economy considered also varies. Some analyses focus on the state economy, while other studies target the regional economy around the port. Other differences among studies include the particular set of port-related activities and types of ports chosen for analysis. Ultimately, the questions that motivate the analysis and the research budget dictate the input-output approach and model used.

The CTR-TTI team met with both the RTI Project Monitoring Committee and the Texas Ports Association (comprising all 25 active Texas ports) in early 2006 after a delayed start of approximately 6 months. At that meeting changes were agreed upon to the proposed study work plan, because many of the larger ports had recently sponsored economic impact studies for the upcoming 2007 Texas Legislative session. Of relevance is that all these studies were undertaken by the same consultant—Martin and Associates, a respected company in the marine economics sector. Accordingly, the following changes were agreed upon and subsequently incorporated into the modified research contract.

- All Texas ports that had commissioned an economic impact study would share the information with CTR to incorporate it into the study documentation. This would avoid any confusion created by different results from the two economic impact studies because of different methodological approaches.
- CTR would conduct economic impact studies for the remaining ports.
- TTI would undertake (a) a deep water channel impact study and (b) a Gulf Intracoastal Waterway (GIWW) and shallow draft channel study, examining the cost consequences of allowing these channel systems to silt up by a certain amount.

- CTR would examine the possibility of measuring the collective impact of maintaining the Texas channel systems on the national (rather than state) economy. The results from the TTI task described were to be used as model inputs.
- CTR would forecast container volumes through the Houston terminals based on time series data. In addition CTR would review the current status of container distribution and activities at other Texas deep water ports contemplating container business.

1.4 Report Outline

The remainder of this report is organized as follows. Chapter 2 focuses on economic impact methods, particularly as they relate to port activities. Specific areas include measuring local and regional impacts with an input-output model and estimating channel maintenance using a computable general equilibrium model developed for the International Trade Commission (ITC). Chapter 3 estimates the transportation cost penalty associated with channel silting—a major concern to Texas port authorities. Chapter 4 describes the use of the ITC model on (a) the Texas portion of the Gulf Intracoastal Waterway and Texas shallow draft ports, and (b) the Texas deep draft channels. Chapter 5 estimates the local and regional impacts for those (mostly smaller) Texas ports that had not sponsored an economic impact study. Chapter 6 describes a method to estimate container flows through Texas ports until 2020. Chapter 7 provides a summary of findings and makes recommendations for future work. In addition, there are a number of appendices that provide the reader with the more detailed, technical data underlying the analyses reported in the main chapters.

Chapter 2. Port Activities and Economic Impact Methodologies

2.1 Introduction

When policymakers make public investments, they are frequently interested in the economic impacts[1] associated with their actions. Stakeholders are usually interested in a policy's economic impact. Common ways of measuring economic impact are the amount of jobs, sales, and tax receipts associated with an activity. These metrics are often reported as evidence that the welfare of a community will be (or is being) enhanced by a policy decision.

2.1.1 Local and Regional Economic Impacts

Ports are maritime transportation assets that facilitate economic activity by acting as gateways where transportation activities and other services facilitate the flow of imported and exported commodities along transportation corridors. At the local or regional level the movement of goods at the port creates employment such as when:

- truck drivers and train conductors deliver or collect cargo to and from the port,
- dock workers and longshoreman operate cranes and machinery to load and unload vessels and manage complex terminals,
- customs officials and Coast Guard personnel regulate international cargo and work with port staff to ensure the security of the port and the nation, and
- pilot services to guide vessels through the various port waterways and access channels.

The jobs, salaries, and output that result from activities at the port are termed the **direct economic impacts** of the port and are frequently estimated using survey methods and economic impact modeling. However, these do not occur in a vacuum and stimulate other related economic activities. Truck drivers must spend money on fuel and maintenance, while businesses at the port (e.g., pilot services and terminal tenants) may purchase insurance and banking services. The economic impacts associated with businesses that conduct transactions with port businesses are called the **indirect economic impacts**. Finally, the spending of the personal incomes (salaries or wages) of individuals employed by those businesses responsible for the direct and indirect impacts also produces economic activity. **Induced economic impacts** are the impacts that result from the consumption of the employees of those businesses generating the direct and indirect economic activity—in this case at a Texas seaport.

Common measures of economic impacts are employment, wages, output or revenue, and tax revenues. While the methodologies that are used to estimate these impacts vary widely in sophistication and detail, the metrics that are reported tend to be consistent. This is because economic impact studies in the maritime realm often employ input-output (I/O)[2] models derived

[1] Economic impacts are distinct from transfers, or redistributions of resources where no improvement to aggregate welfare occurs, and should not be confused.

[2] In the maritime realm, economic impact studies have traditionally been conducted using I/O models or methods derived from Input-Output economics. These models are most commonly suited to providing local and regional analysis. An I/O-based study of California's maritime ports*(1)*, for example, estimated that in 1997 they contributed $40.6 billion to the nation's Gross Domestic Product (GDP). The United States

from I/O economics. These models are most commonly suited to providing users with a local and regional analysis of port impacts. This was the approach used to estimate the local and regional impacts of Texas seaports described in this study and I/O economics are discussed in more detail in Section 2.2.

2.2 Evaluating Local and Regional Impacts with IMPLAN

The local and regional economic impacts of several Texas seaports are estimated in this report through surveys, interviews and the use of a modeling tool called IMPLAN. This model is an Input-Output (I/O) model that is widely used to estimate regional and local economic impacts. Although the principles of I/O modeling are sometimes traced to François Quesnay and his eighteenth-century Tableau Economique, modern I/O models are founded in the work that Nobel Laureate Wassily Leontief began in the 1930s. At the heart of these I/O models are a series of Input-Output tables, which have been developed for many countries around the world. The U.S. Maritime Administration (MARAD) publishes an I/O model specifically tailored to port activities called the Port Economic Impact Kit, or more commonly, MARAD Port Kit. The Bureau of Economic Analysis also publishes Input-Output tables of the U.S. economy and a related set of multipliers called RIMS II. Among the available tools, IMPLAN was chosen because it is regularly updated, regionalized, detailed, and well documented, and supported.

> Input-Output models were used in the 1997 study entitled "The Value of Texas Seaports" that was conducted by the Texas Transportation Institute. I/O models have been used to evaluate the entire U.S. port industry (Department of Commerce, 1977), as well as fishing and recreational activities around the country. In particular, IMPLAN has been used for a large number of regional economic analysis studies.

Within the I/O framework, economic impacts are commonly reported in terms of direct, indirect, and induced impacts (see Section 2.1.1). Direct impacts are usually estimated based on survey results, primary research, and in some cases assumptions about the effects of an investment or policy initiative. The indirect and induced impacts are subsequently derived beginning from a matrix of production relationships, sometimes refined based on the makeup of the key port customers. Input-Output models are capable of providing valuable insight into the nature and magnitude of economic activity at a port. However, compared to more sophisticated models, I/O models face important limitations.

On the one hand, IMPLAN offers a level of detail and sophistication that is not necessarily apparent from viewing the basic model relationships. On the other hand, it employs a set of assumptions that some argue limit its utility. The latter is, however, not specific to IMPLAN, but rather a feature of all basic I/O models and methods that employ I/O multipliers. Some of the most important assumptions are constant returns to scale, a lack of supply constraints, and a lack of input substitution. Constant returns to scale implies that inputs vary proportionally with output. A lack of supply constraints means that industries have "unlimited access" to inputs. The scarcity of resources is thus ignored and the only constraint on how much

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Government's Bureau of Economic Analysis (BEA) compiles Input-Output tables for the U.S. economy as well as a related set of regional economic multipliers called RIMS II. To varying degrees, these BEA products are used by the majority of economic impact estimation tools and methods currently used, including the Computable General Equilibrium (CGE) model which was used to estimate the economic impacts of maintaining selected Texas channels at their authorized depths.

an industry produces is demand. Finally, substitution of intermediate inputs or consumption cannot be accommodated in the model.

While these assumptions may seem reasonable at first glance, they prevent IMPLAN from considering the relationship between demand and price, and price and output. I/O models thus lack the capability to predict economic responses to changes in prices. For example, I/O models cannot predict the effect of a change in maritime shipping costs on the demand for imported and exported goods.

2.3 Analyzing the National Impacts of Channel Maintenance Using a Computable General Equilibrium Model

The previous section entailed a general discussion of the method used to estimate the local economic impacts of several Texas seaports, including the limitations of this method. The researchers applied a Computable General Equilibrium model called USAGE-ITC to estimate the national economic effects of maintaining Texas channels at their authorized depths.

Computable general equilibrium (CGE)[3] models provide a mathematical description of an economy as a complete system. The models represent the inter-relationships among sectors of an economy, including household, industry, government, and external sectors. CGE models of national economies are a subset of national economic models. Compared with macroeconomic forecasting models, their theoretical structure borrows more from mathematical optimization and from a priori assumptions about market structure, which adds to transparency and simplifies parameter estimation. In addition, CGE models have been traditionally used for the evaluation of micro-economic policies as opposed to forecasting. Applications have focused mostly on policies concerning international trade (e.g., tariff levels) and the environment (e.g., carbon taxes), but have extended to other policy areas as well.

Applications of national CGE models to transportation policy have included studies of large-scale infrastructure projects and programs. At the program level, an example is an Australian study that estimated the national economic impacts of potential increases in total highway investment (3). At the project level, examples include studies of the tolled cross-town expressway in Melbourne, Australia (4), and an inter-regional highway project in South Korea (5). Unlike the approach used to calculate local port impacts, the method employed to estimate the national impacts of maritime investment in Texas is unusual. As noted earlier, while CGE modeling has existed for decades, it has rarely (if ever) been used to evaluate dredging issues in the United States.

CGE models are thus well suited to the evaluation of maritime policy. Particularly germane to this research is a 2003 economic analysis[4] of a proposed channel deepening project in the waters off the Port of Melbourne. To estimate national and regional economic impacts, the study used a dynamic multi-regional CGE model of the Australian economy similar to the USAGE-ITC model used in this research study. The impacts measured included, changes in levels of production, employment, wages, and capital stocks. The present value of the changes in real consumption spending over the life of the channel deepening project was estimated as the measure of economic welfare. Of the estimated welfare gain to the nation, about 80 percent was

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[3] CGE models are widely used for policy and trade analysis. The first modern CGE model was developed in 1960 by Leif Johansen. Since then, CGE "modeling has gradually become the dominant economy-wide framework, largely replacing other approaches such as input-output modeling and economy-wide econometric modeling.

[4] PriceWaterhouseCoopers and the Center of Policy Studies conducted the analysis for the Department of Treasury and Finance and the Department of Infrastructure in the state of Victoria. Published in 2007, the report is entitled *Economic Analyses of the Port of Melbourne.*

predicted to accrue to Melbourne's home state of Victoria, where the Port of Melbourne is located.

This section of the report briefly describes the United States Applied General–International Trade Commission (USAGE-ITC) model, provided by the U.S. International Trade Commission to the Center for Transportation Research at The University of Texas at Austin. The USAGE-ITC model is an adaptation of the Australian MONASH[5] model, which has a 20-year lineage and has been adapted to model a large number of national economies.

The theory and mathematics behind the USAGE-ITC model is complex and the technical details of the model are beyond the scope of this report. Interested readers are referred to "Dynamic General Equilibrium Modeling for Forecasting and Policy: A Practical Guide and Documentation of MONASH" by Dixon and Rimmer and "USAGE-ITC: Theoretical Structure" by Dixon and Rimmer. However, the following sections provide an overview of the USAGE-ITC model framework and specification of the model.

2.3.1 The USAGE-ITC Model Framework

The USAGE-ITC framework has three components:

- a set of I/O accounts;
- behavioral parameters; and
- a system of economy-wide conditions.

The I/O accounts specify the transactions among all economic agents in the U.S. economy for 2002, the base year for the current version of USAGE-ITC. The model's I/O accounts are derived from the I/O accounts published by the Bureau of Economic Analysis.

While the I/O accounts specify the initial equilibrium for the U.S. economy, behavioral parameters determine how economic agents would respond to an exogenous change. USAGE-ITC is thus a more realistic model compared to I/O models, because it accounts for the behavior of economic and the treatment of prices. The following behavioral parameters[6] are used by USAGE-ITC:

- Elasticities of substitution between imported and domestic goods;
- Elasticities of import supply and export demand;
- Elasticities of input substitution for U.S. producers; and
- Income and price elasticities for U.S. households.

Where possible, parameters have been estimated. In other cases, parameter specification relied on published studies. For example, the elasticities of substitution between imported and

[5] MONASH was developed at the Center of Policy Studies (CoPS) at Monash University. USAGE-ITC was developed as a result of collaboration between the developers of MONASH, and the U.S. International Trade Commission.

[6] Consumption and production are determined through mathematical optimization. In particular, producers are assumed to be revenue maximizing and cost minimizing. Consumer demand for commodities is derived assuming consumers are maximizing their utility. USAGE-ITC allows producers and consumers to choose between substitute goods and to alter their behavior in response to price changes. These relationships are a function of the elasticities within the model.

domestic goods (i.e., the Armington elasticities) are documented in Donnelly et al.[7] and Hertel et al.[8]

The final component of the USAGE-ITC framework is a system of three general conditions that ensure a competitive general equilibrium:

- First, all constant returns activities must earn zero profits. This does not imply that firms do not earn income in excess of their costs. Rather, this refers to economic profits. It implies that in the long run, in competition, firms will not earn a level of income that exceeds their risk-adjusted cost of capital. When economic profits above the cost of capital exist, there is incentive for additional actors to enter the market, and the competitive forces exerted by these new entrants will drive profits back to the long-run risk-adjusted cost of capital. In other words, firms tend to earn average returns over the long-run,
- Second, the market for each product must clear so that supply equals demand, and.
- Finally, it is assumed that income is exhausted on final demand and savings.

2.3.2 Specification of the USAGE-ITC Model

The USAGE-ITC model considers three separate components of domestic final demand:

- household consumption
- government demand
- and investment demand

Household consumption is derived from a linear expenditure system (LES) of commodity demands.[9]

On the other hand, in the specification of government demand, real government spending is fixed exogenously. This condition is satisfied by endogenously adjusting government transfers to households. This adjustment assumes that changes in government revenues are compensated through a tax.

In the case of investment demand, capital creators in an industry are assumed to choose their input mix to minimize the costs of producing new capital subject to a constant-returns-to-scale capital-creation function. The only prices affecting the demand for domestic and imported inputs to capital creation are the prices of these inputs. Unlike current production, for capital creation there are no inputs of primary factors. The use of primary factors in capital creation is recognized via inputs of construction and other investment-related services.

Input-output technologies are modeled using nested substitution/transformation functions. Value-added and intermediate inputs are combined to produce a composite industry output (or industry activity level). Value-added inputs are labor, capital, and land. Intermediate inputs do

[7] Donnelly, William A., Kyle Johnson, Marinos Tsigas and David Ingersoll. Revised Armington Elasticities of Substitution for the USITC Model and the Concordance for Constructing a Consistent Set for the GTAP Model. Office of Economics Research Note No. 2004-01- A. Washington, DC: Office of Economics, U.S. International Trade Commission, January 2004.

[8] Hertel, Thomas, David Hummels, Maros Ivanic and Roman Keeney. *How Confident Can We Be in CGE-Based Assessments of Free Trade Agreements?* GTAP Working Paper No. 26. West Lafayette, Indiana: Center for Global Trade Analysis, Purdue University, May 2003.

[9] P.R.G Layard, A.A. Walters. *Microeconomic Theory*. McGraw Hill, New York. 1978.
Deaton, Angus and Muellbauer, John. *Economics and Consumer Behavior*. Cambridge University Press, 1980, Chapter 5.

not substitute for one another and for value-added (i.e., Leontief specification is applied). Intermediate inputs are material and service inputs used in production of final goods.

Land, capital, and labor are combined to produce value-added inputs. Substitution possibilities between land, labor, and capital are based on the constant ratios of elasticities of substitution, homothetic specification (CRESH).

For each commodity in USAGE-ITC there is a distinction between two varieties. There is a *domestic variety* destined for domestic consumption and exports and a *foreign variety* destined for domestic consumption. In each case, the substitution potential between the two varieties (i.e., the degree of product differentiation) is specified with a constant elasticity of substitution (CES) parameter, which is often referred to as the "Armington" elasticity.[10] The modeling of trade equilibrium is completed by defining constant elasticity export demand and import supply functions. By defining these functions, the model characterizes the rest of the world.

2.4 Concluding Remarks

USAGE-ITC is particularly well suited to the evaluation of certain elements of domestic water transportation, such as the example of the national economic impacts of a reduction in the depth of Texas' shallow draft channels. The model can be used to estimate the impacts of price changes to a wide selection of commodities within the economy. Within this set of commodities exists a special class called "margin commodities." Margin commodities "facilitate flows of [non-margin] commodities from points of production or ports of entry to either domestic users or ports of exit." The margin commodities included in USAGE-ITC are water, air, truck, rail, natural gas pipeline, all other pipeline, and wholesale trade and retail trade transportation services (1, 2).

It is important to differentiate both the method and the results of the AGE approach from studies that measure port business activities. The principal difference is that direct impacts are not viewed in terms of sales or jobs but rather in terms of cost savings and penalties. The size and quality of the maritime infrastructure can influence the cost of water transportation in that it determines the type and size of vessel that can be served at the port. Therefore, the cost of water transportation ultimately impacts the cost of trade. Time, weather and the natural hydrodynamics of a waterway cause channels to silt up. Although channels deteriorate unevenly, a ship must be able to traverse the shallowest portion of a channel. If any segment of a channel deteriorates to the point that it impedes navigation, costly maintenance must be undertaken. In practice, U.S channel maintenance has been regularly scheduled by the U. S. Army Corps of Engineers; however, when it is not, diminished channel depths force ships to be loaded with less cargo. Loading ships with less cargo means that they carry less weight, measured in tons, and causes a ship to sit higher in the water, with less of the hull below water. Sitting higher, it can safely traverse a shallower channel. However, this also increases the cost of moving a given amount of cargo.

The direct economic impacts associated with channel dredging are, therefore, estimated by a reduction in the cost of water transportation. Ultimately, the final cost of a good that a consumer buys reflects the sum of the price of the materials used in its construction, the cost of the services that are utilized in its manufacture—including the cost of transporting the product at each stage of its journey from raw material to finished good to final purchase—and any profit that the seller can charge. When the price of goods increases due to higher transportation costs,

[10] Armington, P. S. *A Theory of Demand for Products Distinguished by Place of Production,* IMF Staff Papers 16, March 1969, pp. 159–76.

productivity is decreased because less output (trade goods) can be moved with the same inputs. This can decrease the competitiveness of goods and so result in decreased trade and thus economic activity at the ports. The next chapter estimates those increases for Texas shallow and deep draft channels.

Chapter 3. Transportation Cost Penalty Associated with Channel Siltation

The analysis of the costs associated with a lack of maintenance dredging focused on two components: (1) the cost of dredging, and (2) the cost[11] of transporting commodities between two end points. However, in any "real world" situation in which severe draft restrictions are implemented, other economic consequences may (and probably will) accrue. The latter includes but is not limited to

- industrial relocations,
- reductions in consumption or sales,
- diversion of cargo to other ports,
- loss of ability to compete for "subsistence" areas,
- effects on national security,
- potential rise in vessel chartering costs due to increased demand for smaller vessels, and
- An increased probability for a collision, oil spill, fire, or other adverse environmental consequence due to an increase in the number of lightering operations.

While it is possible that deepening a channel (or optimizing its dimensions) could significantly increase deeper draft traffic, the analysis presented in this chapter focuses on the channels as they were at the end of 2005. The channels analyzed by the study team are

- Gulf Intracoastal Waterway (for all of Texas and in three separate reaches),
- Chocolate Bayou,
- Arroyo Colorado (Port of Harlingen),
- Channel to Victoria,
- Port of Brownsville,
- Port of Corpus Christi,
- Port of Port Lavaca,
- Port of Galveston,
- Port of Texas City (used to compare with Martin's approach)[12]

[11] In analyzing the cost of transporting commodities, the inverse of the concept of "National Economic Development (NED) Benefit," as defined by the US Army Corps of Engineers (USACE), was used. The NED Benefit is defined as the "*reduction in the value of resources required to transport commodities.*" This concept is typically used to demonstrate the potential benefits of deepening or widening a channel. However, in this study, the focus is on the increased costs associated with a channel becoming shallower or narrower. In other words, by maintaining channels at their authorized depth, the federal government reduces the cost of transporting commodities. Failure to dredge will increase the cost.

[12] The details of two different analyses of the Texas City Channel conducted as part of this project are included in Appendix B.

When channels are not maintained, transportation costs increase as follows:

1. Vessels must be "light loaded" (i.e., loaded to less than capacity) for the draft of the vessel to be reduced to the point where it can safely navigate the channel. This increases the cost-per-ton (or barrel) to transport the commodity on the vessel.
2. The commodity that was "removed" from the vessels must still be transported to maintain the same level of economic activity. Additional vessel voyages will thus be required. All these voyage costs are additional transportation costs that would not have been incurred if the channel were maintained at its authorized depth.

For purposes of this analysis, it was assumed that the volume of cargo moved will be constant. In other words, industry will maintain the same level of economic activity and move the same amount of cargo. The point at which this assumption is no longer valid is beyond the scope of this research.

The channels represent (1) deep draft channels connecting port facilities with the Gulf of Mexico, and (2) the Gulf Intracoastal Waterway (GIWW), along with certain "tributary" channels. Several Texas ports undertook similar analyses that were done by the consulting firm of Martin and Associates ("Martin"). The study results of the latter are included in this document without further analysis.

This chapter of the report documents the data sources and methodology applied to calculate the transportation cost penalty associated with the silting of the deep draft channels and shallow draft channels.

3.1 Shallow Draft Channels

Detailed data were obtained from the Colorado River Lockmaster for Calendar Year 2005 (to gain an understanding of tow sizes, drafts, and loads). According to the Executive Director of the Gulf Intracoastal Canal Association, this data is a reasonable representation of all traffic along the Texas coast. Because of the large volume of data, four months were randomly selected for analysis: January, April, September, and December. Furthermore, the analysis segregated liquid cargo movements from dry cargo movements. Appendix A summarizes the statistics derived from the Colorado Lock data and waterborne commerce statistics.

This analysis examined the effect of allowing the shallow draft channels to silt in to the point where barges are limited to a maximum draft of 8 feet. For both liquid and dry cargo movements, the following statistics were calculated (see Appendix A):

- Average draft for barges exceeding 8 feet of draft,
- Average empty draft,
- Weighted average tons per barge for barges exceeding 8 feet of draft,
- Cargo tons per foot of draft, and
- Average number of barges per tow when barges draft more than 8 feet.

These statistics were then used to analyze the effect on transportation costs if barge drafts were limited to 8 feet. The analyses were based on the latest cargo and trip information available from the United States Army Corps of Engineers (USACE) as reported in "*Waterborne Commerce of the United States*, Calendar Year 2004, Part 2–Waterways and Harbors, Gulf

Coast, Mississippi River System and Antilles." This report was used to ensure consistency across all shallow draft channels.

Cost information for operating towboats and barges were taken from USACE's Economic Guidance Memorandum 05-06, which provides shallow draft vessels operating costs for 2003. An adjustment was made to fuel cost because of the dramatic increases in fuel costs since 2003.[13] The other operating costs, reported by USACE, were inflated using the Inland Waterways Towing Transportation Producer Price Index.

The 1800-2000hp category was used for the towboat horsepower in this analysis. A speed of 5 mph was assumed. For tank barges, the costs of a 297.5' x 54' x 12' tank barge without coils were used. For dry cargo, costs for the 195' x 35' 12' covered hopper were used.

The average trip length was computed for each channel being analyzed using USAGE data. The average trip duration was then determined by dividing the trip length by 5 mph. Using the USACE cost data and trip duration, the average trip costs for tank barge tows and hopper barge tows could be estimated.

The analysis[14] was performed separately for hopper barges and tank barges for each waterway or channel. The steps involved are briefly provided here.

- Estimate the average cost per ton for cargo moved by channel in barges exceeding 8 feet of draft in CY 2005 as follows:
    1. Determine the number of barges drafting more than 8 ft in 2004 from USAGE data.
    2. Divide this number by the average number of barges per tow (as determined from lock data), to derive the number of trips involving barges drafting more than 8 ft.
    3. Multiply the number of trips by the calculated trip cost.[15]
    4. Estimate the "actual" tonnage moved on these barges by multiplying the weighted average tons per barge for barges drafting more than 8 ft (as determined from lock data) by the number of barges exceeding 8 feet of draft.
    5. Determine the average cost per ton by dividing the total trip costs by the "actual" tonnage.
- Calculate the difference in cost per ton attributable to a reduced draft as follows:
    1. Calculate the difference between the weighted average draft of barges exceeding 8 feet of draft and 8 feet.
    2. Determine how much tonnage[16] need to be removed from the average barge (exceeding 8 feet of draft) to make it draft 8 feet.
    3. Multiply the "adjusted" tonnage[17] per barge by the number of barges obtained in Step 1.

[13] The fuel cost per gallon for this analysis is: $2.015 ($1.815 average No. 2 High Sulfur Diesel Fuel Price for 2005 + $0.20 Waterway Tax.), which is 173% of the cost in the USACE schedules. The Deficit Reduction Tax of $0.043 is set to expire on January 1, 2007, and was therefore excluded.
[14] See Appendix B for an illustrative example of these calculations for the Texas reach of the GIWW.
[15] The trip cost comprises the cost of the average number of barges per tow plus the cost of the tow boat over the distance of the trip.
[16] Use the tons/feet derived from the Colorado Lock Data.
[17] The "adjusted" tonnage is the tonnage that remains on the barge after the barges had been "lighter loaded" to ensure a draft of 8 feet.

4. Divide the total trip[18] cost by this new (reduced) tonnage amount to obtain the adjusted cost per ton
5. Finally, the "adjusted" tonnage transported under the reduced draft scenario by the difference in the two cost-per-ton[19] calculations.

Figure 3.1 provides a graphical illustration of the analysis to calculate the cost per ton effects of a shallower draft.

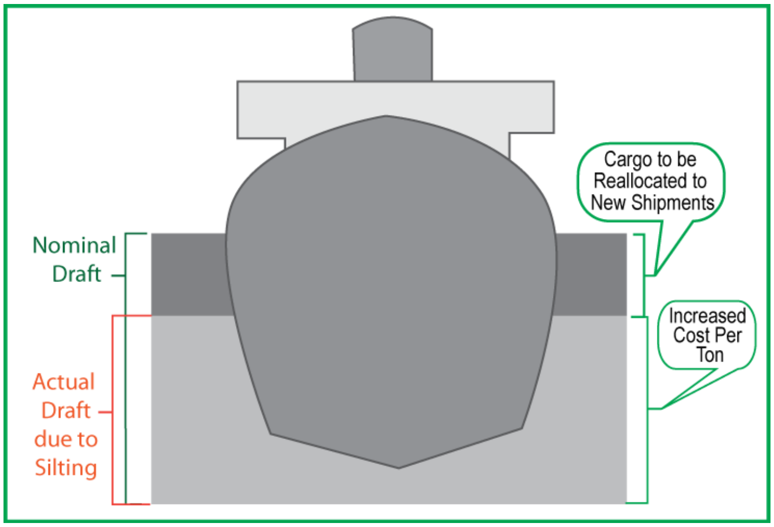

Figure 3.1: Cost per Ton Effect of a Shallower Draft

However, the cargo that was removed from the barges to prevent them from drafting more than 8 feet must still be transported to maintain the same level of economic activity. Shippers would thus have to book more shipments using the draft-restricted barges or load more into barges that drafted less than 8 ft in 2005. The latter approach would, however, require changes in the timing of shipments. The more likely approach is thus the booking of additional shipments—at least for the short to medium term.

1. Determine the number of additional trips required by dividing the total tonnage that had to be "removed" from the barges that drafted more than 8 feet by the average barges per tow calculated previously.
2. Multiply the number of additional trips by the average trip cost.[20]

The total additional transportation costs incurred when barge drafts have to be restricted to 8 feet is the sum of the cost per ton increase of the "lighter loaded" barges and the cost of the new shipments necessitated by the shallower draft.

[18] The trip cost is almost exactly the same regardless of the tonnage moved. Therefore, barge operators would be moving less cargo at the same cost. This means that the cost per ton of cargo moved increase.
[19] The cost per ton for barges drafting more than 8 feet during 2005 and the cost per ton for barges if they had been restricted to 8 feet are known. The total effect of the increase cost per ton for these barges can thus be calculated.
[20] The cost of the average number of barges per tow plus the cost of the towboat over the trip distance.

Dredging Costs

It should be noted that dredging costs can fluctuate significantly from year-to-year depending on the demand for dredging. When major storms occur or a large number of ports initiate channel improvement projects, dredging costs may soar. There is a limited supply of dredging equipment, which makes the cost of dredging volatile.

The analysis also considered USACE's spending on maintenance dredging of the selected channels. USACE does not calculate the cost of not performing maintenance dredging. Therefore, the potential cost savings associated with not maintaining the channels was assumed to be the average of what USACE spent on maintenance dredging (i.e., contracts issued to dredging contractors) for a given channel from 1998 through 2005. In reality, these figures probably underestimate the cost savings, because most of the channels along the Texas coast have suffered from a lack of maintenance dredging in recent years. The cost data used were taken from the *Fiscal Year Annual Report of the Secretary of the Army on Civil Works Activities Extract, Galveston District* for FY 1998-2005. These costs were then expressed in 2005 price levels using the Producer Price Index for Other Heavy Construction. Only the costs related to dredging and dredging-related work were considered. The "all-in" cost figure, which includes USACE overhead and internal allocations, was NOT used. The implicit assumption was that USACE will not reduce its force or significantly alter its internal cost structure under analyzed scenarios.

It is important to note that the dredging cost savings are only realized up to the point where the targeted reduced channel depth occurs. After this point, dredging must resume or the channel will silt even further. However, the impacts (i.e., transportation cost penalty) begin to accrue immediately and continue "forever" unless the Corps decides to dredge down to the authorized channel depth. In other words, the dredging cost savings are a "one-time" event, whereas the additional transportation costs will be incurred "forever."

The results of the analyses are summarized in Table 3.1. It is important to note that it is not possible to simply add the three Texas reaches of the GIWW to obtain the economic impact for the whole Texas coast. This is because many trips span two or more reaches of the GIWW and within each reach they are counted as a separate trip. To simply add the reaches would thus double- or triple-count many trips. The results for the row labeled "GIWW: Texas" reflect a consolidation of the trip data to eliminate multiple-counting.

Table 3.1: Dredging Impacts On Texas' Shallow Draft Channels
(8 ft draft restriction for barges)

		Liquid		Dry				
Channel	**Avg Trip Length**	**Number of Barges Affected**	**Transportation Cost Savings Due to Maintenance Dredging**	**Number of Barges Affected**	**Transportation Cost Savings Due to Maintenance Dredging**	**Annual Dredging Cost**	**Total Transportation Cost Savings Due to Dredging**	**Ratio of Savings from Dredging to Cost of Dredging**
Chocolate Bayou	256	1,247	3,482,434	- 0 -	- 0 -	409,488	3,482,434	8.5
GIWW: Sabine to Galveston	523	14,286	83,520,732	4,179	12,282,006	3,263,228	95,802,738	29.4
GIWW: Galveston to Corpus Christi	394	7,941	34,816,170	1,382	3,059,810	11,506,266	37,875,980	3.3
GIWW: Corpus Christi to Brownsville	460	576	2,929,941	198	517,156	2,822,352	3,447,097	1.2
GIWW: Texas	431	19,478	93,153,887	4,022	9,681,115	17,591,846	102,835,002	5.8
Arroyo Colorado (Harlingen)	322	168	609,901	91	176,636	691,408	786,537	1.1
Channel to Victoria	278	853	2,614,807	143	222,198	1,402,393	2,837,005	2.0

It is also important to note that towboats would draft at least one foot more than barges. This is because there is typically considerable sloughing along the sides of the GIWW. To avoid grounding a barge, operators typically allow 2 feet of clearance in determining their barge loads. However, towboats are not as wide as the barge tow and tend to stay near the center of the channel. They can thus be allowed to run with 1 foot less of clearance.

Table 3.2 shows the potential effect of a restricted draft on the ability of towboats to operate at maximum efficiency.

Table 3.2: Potential Effect on Towboats.
(Based on USACE Waterborne Commerce Statistics for 2004)

Waterway	**Tow Trips Reported in 2004**	**Tow Trips Affected by 9-ft Draft Restriction**	**Percent Affected**
Chocolate Bayou	2,172	40	1.8
GIWW: Sabine to Galveston	25,576	4,096	16.0
GIWW: Galveston to Corpus Christi	18,157	634	3.5
GIWW: Corpus Christi to Brownsville	2,361	14	0.6
GIWW: Texas	40,126	4,614	11.5
Arroyo Colorado (Harlingen)	247	0	0.0
Channel to Victoria	2,472	206	8.3

If the restricted draft scenario were compared to what the towboats would draft with a full load of fuel and water (as reported by USACE), approximately 11 percent could be draft-restricted. Therefore, for the GIWW and the Channel to Victoria it is possible that anywhere from 8 to 12 percent of the towboats working on these channels could find themselves incapable of taking on a full store of fuel and water, thereby reducing their efficiency or causing them to be redeployed elsewhere. This effect on towboat utilization was not quantified in this analysis. If accounted for it will increase the calculated effects significantly.

Finally, after the research was completed and a draft report issued, some members of the Texas Ports Association requested that impacts of restricted draft be undertaken for the Colorado River (thereby including the Port of Bay City). This information is reported in Appendix C, which estimates the benefit of maintaining an 8 foot depth on the Colorado River at $256,430.

3.2 Deep Draft Channels

The data used for calculating the deep draft channel impacts were for Calendar Year 2005. The data sources used for the analyses are listed here:

- Vessel traffic information were provided by Port authorities to varying degrees of detail,
- Pilots provided vessel traffic information for Texas City and Galveston,
- Information on arrivals that were used to identify origins/destinations of domestic cargos were provided by the Coast Guard,
- The Journal of Commerce PIERS database was used to determine vessel tonnages and last/next ports of call,
- Lloyd's Register provided the following vessel-specific information:

  Vessel Type;

  Flag of Registry;

  Maximum Draft;

  Deadweight Tonnage; and

  Tons/per Centimeter Immersion (TCI)[21]

- Distances between ports were determined using Lloyd's Register, Ports & Terminals Guide 2005, and
- USACE's EGM 02-06 was used to compute service speed, daily cost at sea, deadweight tonnage (DWT), and a cargo capacity factor[22] by vessel type.

The analysis steps[23] in calculating the transportation cost savings associated with dredging the deep draft channels are briefly described in this chapter. The first step in the analysis was to determine the baseline draft. The maximum sailing draft reported by the port (or pilots) were used as the baseline draft rather than the official "project draft" reported by USACE. Actual sailing drafts are a better indicator of the condition of a channel than the design features. Five feet were subtracted from the baseline draft to estimate the effect of siltation--an approach that is consistent with the approach followed by Martin & Associates. Vessels with a maximum draft less than or equal to the reduced draft were excluded from further analysis. The remaining vessels were examined on an individual basis.

- For arriving or departing vessels draft exceeding the adjusted draft (i.e., baseline minus 5 feet) the distance from the port to the relevant port of last call or next call was determined from *Lloyd's Register Ports & Terminals Guide 2005*.

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[21] In a number of cases, the TCI was not available. In these cases, the TCI was computed using equations developed by USACE, provided in Economic Guidance Memorandum 02-06, Deep Draft Vessel Operating Costs (EGM 02-06). In a few cases, the maximum draft was not available and calculations contained in EGM 02-06 were used in these instances as well,.

[22] Cargo capacity factors were obtained from USACE's National Economic Development Procedures Manual: Deep Draft Navigation, IWR Report 91-R-13. These factors were used to convert DWT to actual cargo carrying capacity.

[23] Data from the Port of Brownsville were used to illustrate the analysis steps in Appendix C.

- For each vessel transit exceeding the adjusted draft, the following were calculated:

  Days at sea: Distance to/from port divided by service speed for vessel type and DWT.

  Cost of voyage: The days at sea multiplied by the daily cost at sea (per USACE).

  Required draft reduction: The difference between the actual sailing draft and the adjusted draft.

  Required tonnage reduction: The required draft reduction multiplied by the TCI immersion factor.

In the case of some ports, a significant number of vessels discharged less than their full load or loaded additional cargo at the port. Because the ports only report the cargo discharged or loaded at the particular port of call, the total tonnage on board needed to be calculated to estimate the cost per ton for the voyage. The actual cargo carrying capacity for each vessel type (excluding fuel, ballast, stores, etc.) were calculated by multiplying the cargo capacity factors supplied by the Corps in *National Economic Development Procedures Manual: Deep Draft Navigation, IWR Report 91-R-13* by the DWT. The total cargo moved on the voyage was estimated by subtracting the difference between the maximum draft and actual sailing draft multiplied by the TCI factor from the actual cargo capacity.

The tonnage that had to be removed from each vessel was obtained by multiplying the difference between the reported sailing draft and the calculated reduced channel depth by the TCI factor. This number was subtracted from the calculated total cargo tonnage moved on the voyage, and the cost per ton[24] associated with this reduced tonnage was re-calculated.

The difference (penalty) in cost per ton was then multiplied by the tonnage the affected vessels could carry with a shallower draft, summing the latter over each of the affected voyages, thus providing an estimate of the total impact of reducing the cargo loads on the affected vessels.

Figure 3.2 provides a graphical illustration of the analysis to calculate the cost per ton effects of a shallower draft for the deep draft channels.

[24] Similar to the barges, the voyage cost is almost exactly the same regardless of the tonnage moved. Therefore, vessel operators would be moving less cargo at the same cost. This means that the cost per ton of cargo moved increases.

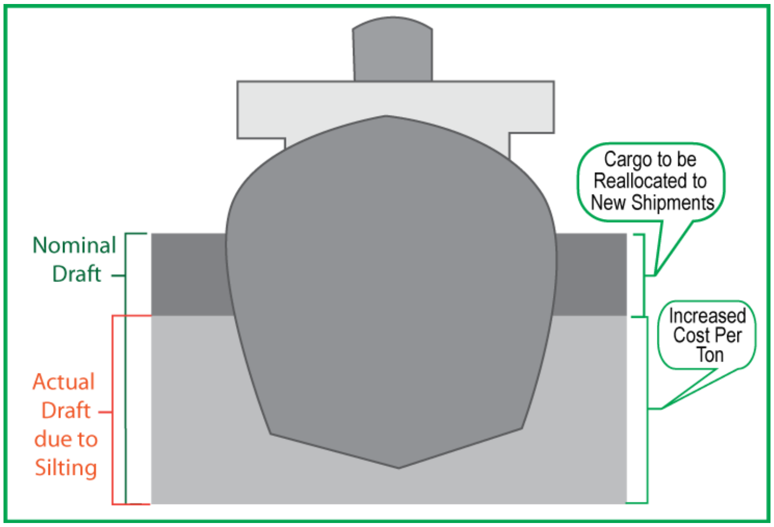

Figure 3.2: Cost per Ton Effect of Shallower Draft.

Again, similar to the barges, it is necessary to calculate the cost of transporting the cargo that had to be removed due to the shallower channel, keeping mind that these additional voyages will be subject to a reduced channel depth. The "excess" tonnage— the total tonnage removed because of the new draft restriction—per vessel type (tanker, bulker, and general) was calculated. The number of additional voyages required to move the "excess tonnage" was then calculated by dividing the "excess" tonnage associated with a particular vessel type by the average adjusted tonnage[25] for that vessel type.

If the number of additional voyages resulted in less than half a vessel load it was assumed that the "excess tonnage" could be distributed among other shipments. If the results exceeded half an average vessel load, it was assume that an additional voyage would be required.

The weighted cost per voyage for each vessel type was subsequently calculated by multiplying the number of additional trips required by that vessel type by the cost per voyage for each type.

The additional voyage costs were then added to the cost-per-ton penalty calculated earlier to obtain the total additional transportation costs incurred necessitated by the shallower draft.

3.3 Dredging Costs

As with the shallow draft channels, data on the maintenance dredging costs for the deep draft channels from 1998 through 2005 was acquired from USACE. USACE also provided channel surveys from late 1998 through early 2006 to the research team. The data was briefly examined for the five deep sea channels included for analysis in this research study. The data suggested that, absent major hurricanes, it would take anywhere from 15 to 30 months for a segment of a given ship channel to silt in 5 feet. In an active hurricane season, it could take *2 to 6 months*.

Table 3.3 summarizes the results of the analysis for the deep draft channels as calculated by the research team and the analysis results for a selected number of channels that were evaluated by Martin and Associates.

[25] The adjusted tonnage is the tonnage that can be moved on the vessel given the reduced channel depth.

Table 3.3: Dredging Impacts on Texas' Deep Draft Channels (Base draft minus 5 feet)

Channel	Base Draft	Adjusted Draft	Affected Voyages [In ---- Out]	Total Voyages[26] [In ---- Out]	% Affected [In ---- Out]	Additional Voyages Required [In ---- Out]	Tonnage Reduction [In ---- Out]	Transportation Cost Savings Due to Maintenance. Dredging [In ---- Out]	Annual Cost of Dredging	Total Transportation Costs Savings Due to Dredging	Ratio of Transportation Cost Savings from Dredging to Cost of Dredging
TxDOT Study:											
Brownsville	39	34	43	171	25	3	128,307	1,451,322	2,475,626	1,502,840	0.6
			6	45	13	0	21,338	51,518			
Corpus Christi	45	40	156	937	17	11	824,602	5,229,181	4,209,320	5,812,578	1.4
			12	677	2	1	72,718	583, 397			
Galveston	40	35	4	151	3	0	11,332	22,672	3,299,245	2,136,777	0.8
			43	211	20	3	120,505	2,114,105			
Port Lavaca	36	31	46	67	69	7	179,010	1,212,607	2,758,767	3,197,223	1.2
			28	165	17	3		1,984,616			
Martin & Associates:											
Texas City	38	33							1,218,496	27,900,000	22.9
Freeport	42	37							3,625,471	7,572,685	2.1
Sabine-Neches (Beaumont-Pt Arthur)	37	32							8,670,559	198,524,000	22.9
Houston[27]	N/A	-5							6,690,931	582,403,880	87.0

[26] Voyages with cargo to/from this port, including oceangoing barges
[27] The methodology assumes that every vessel will be affected by a change in draft; that is, if the draft reduces one foot, then every vessel will have to lighten its load enough to reduce its draft by one foot.

3.4 Summary

This chapter presented the costs impacts of reducing channel depth by 5 ft for a variety of channels and waterways. Shallow and deeper draft ports all are negatively impacted by the rise on costs that accompany a draft reduction on Texas waterway channels. The data provide an insight into the cost-benefit (C/B) ratio associated with each channel and the GIWW, when the most recent USACE dredging cost is compared with the change in transportation cost for the waterway sections considered. It should be noted that the ratio for the CTR/TTI work is "de minimus" because using changes in transportation cost alone leaves out other key benefits that would drive up the C/B ratio. But it does show the importance of dredging in contributing to port efficiencies. There are also differences in how the transportation costs were calculated between the TxDOT researchers and Martin and Associates, which also complicates any comparisons between the two sets of numbers.

The work reported in this chapter is valuable "stand alone" data for enriching a variety of policy, planning, and funding initiatives. It also forms a major input to the model chosen to measure the impacts of the Texas ports on the U.S economy and this is presented in the next chapter.

Chapter 4. The National Economic Impacts of Maintaining Texas' Waterways

The research team selected a Computable General Equilibrium model, USAGE-ITC discussed in Chapter 2, to evaluate the national economic impacts of a reduction in the authorized depths of selected channels. The analyses were conducted separately for deep draft and shallow draft channels. Deep draft channels tend to be associated with larger ports and facilitate the movement of larger vessels while shallow draft channels typically handle primarily barge and small vessel traffic. The commodity traffic also tends to differ by channel depth. While both deep and shallow draft channels handle large amounts of bulk cargo in Texas, shallow draft channels tend to handle very little high-value per-ton and containerized cargo. This chapter of the report presents the model approach and then provides the analysis results first for the shallow and then deep draft channels.

4.1 The Gulf Intracoastal Waterway and Texas' Shallow Draft Channels

This section of the report documents the analysis of the national economic impacts of a reduction in the depths of three Texas' shallow draft channels and the Texas Gulf Intracoastal Waterway (GIWW).

Using USAGE-ITC to derive these results requires that two major steps are undertaken, first defining the "closure" and then developing the "shock." The closure is a specification of the variables that are exogenous and endogenous. The shock is the policy change—in this case a reduction in channel depth—that will move the model to a new equilibrium. The closure must be done with care for several reasons:

- First, the closure must be theoretically consistent with the shock that is being evaluated,
- Second, the closure must result in an invertible matrix. That is, it must be square and non-singular, among other things, and
- Third, because USAGE-ITC uses a large amount of computing resources, the closures specified must be computed with the available resources. The model closure and "shock" developed are discussed subsequently.

4.1.1 The Model Closure

The closure specified for this research resulted in the following nine assumptions, which underlie the analysis:

1. The policy shock has no effect on real national savings. Thus, it is assumed that the quantity of capital owned by U.S. residents is unaffected by the shock.
2. Real government expenditures are not affected by the shock.
3. The ratio of real public consumption to real private consumption is unaffected by the shock.

4. Real private consumption is related to real disposable income. The government adjusts the tax rate on labor income to ensure that the shock-induced movement in real private consumption is consistent with maintenance of real national savings.
5. The ratio of investment to capital (I/K) in each industry is held constant. Because the ratio I/K is a reflection of business confidence, this assumption means that the shock has no long run effect on business confidence. Nevertheless, aggregate investment can move relative to aggregate capital due to variations between industries and their I/K ratios.
6. The average rate of return on capital across industries is assumed to be unaffected by the shock. This assumption is consistent with the idea that capital stocks adjust to ensure rates of return are in line with interest rates adjusted by risk premia and that interest rates and risk premia are independent of the policy. However, capital would earn higher rates of return in industries favored by the policy and lower rates of return in industries that are harmed. The rate-of-return assumptions mean that the simulation depicts long-run effects. The parameters were set to provide impacts after about 5 years.
7. Real wage rates adjust so that the policy has no effect on aggregate employment.
8. The shock has no effect on technology or consumer preferences.
9. The shock has no effect on the aggregate price index for private consumption; that is, this aggregate price index is the numeraire price.[28]

Development of Model Shocks

The price change resulting from that policy decision must be estimated to evaluate the national economic impacts of a reduction in the depths of shallow draft channels, This price change is the "shock" to the model that forms the basis for the computation of a new equilibrium. Within USAGE-ITC, the changes in prices and markets are expressed as percentages. Shocks must also be expressed as percent changes.

The shocks used in this work were developed on the basis of a per-ton cost penalty associated with the siltation of shallow draft channels and the Texas GIWW. The previous chapter described the method used to calculate these penalties and Appendix A gives further details on the calculation of the cost penalty for both the shallow and deep draft channels. This section summarizes the salient assumptions and approach followed. The cost penalty was calculated assuming that:

1. The same amount of cargo is moved whether the channel is maintained to its authorized depth or it is allowed to become shallower. In other words, the volume of cargo is held constant, and
2. Shippers and barge operators do not adopt vessels with operating characteristics that will allow them to operate in shallower channels. This is a reasonable assumption, as barges (the primary means of moving goods on these channels) in the United States are built to specifications that assume a 12 foot operating draft.

[28] USAGE-ITC is not a monetary model. This means that if changes are not calculated on the basis of the overall level of prices, but on the basis of relative prices, a benchmark must be chosen from which to express the changes. This benchmark is called a *numeraire*.

Furthermore, for each channel, a depth shallower than the authorized depth[29] was chosen. The channel depths used in the analysis correspond to the maintenance of three Texas shallow-draft channels at their authorized depth and at a level 5 feet shallower. The research team evaluated the impacts of the siltation of GIWW (to less than) its nominal depth of 12 feet.[30] The siltation of Texas shallow draft channels means that they need to be periodically maintained (i.e., dredged) to remove sediment, thereby returning them to a depth at or near their authorized depth. In periods between dredging, vessels must be loaded to a weight that allows them to clear the shallowest segment of the channel. The more cargo weight a vessel carries, the deeper it sits in the water, and this necessitates a correspondingly deep channel to avoid running aground. Because the operating cost of a vessel is largely fixed for a given journey, cargo can be loaded on a vessel if the channel depth decreases. The cost of transporting each ton of cargo consequently increases.

The increase in the per-ton cost is, however, only the cargo that allows the vessel to sit higher in the water must still be moved, assuming the same cargo tonnage. This necessitates additional vessel voyages and consequently additional cost. The calculation of the per-ton cost associated with a 5 foot reduction in the authorized depth of three Texas channels and the Texas portion of the GIWW are detailed in Chapter 3.

The three channels evaluated in this report are

- Chocolate Bayou (a waterway serving the petrochemical industry),
- Arroyo Colorado (the channel that serves the Port of Harlingen) and
- the Channel to Victoria (serving the Port of Victoria)

Estimating the costs associated with the siltation of these channels and a section of the GIWW required the collection of data on the vessel voyages on each channel as well as discussions with shippers and barge companies. This enabled the research team to estimate the number of voyages on each channel that was affected by siltation of five feet. Given the affected voyages, the increased costs attributable to channel siltation as explained in the previous paragraphs were calculated. These costs form the basis for the application of the USAGE-ITC model.

Regionalizing the Shock

In other words, USAGE-ITC does not accept "regional" inputs in the sense that they cannot be specified in a geographic form that shows the policy shock originating in Texas. This is particularly important, because shocking USAGE with simple percentage price changes will generate results that assume the price increase affects the GIWW, the Great Lakes, the Mississippi River, and so forth. Non-regionalized shocks thus may over-estimate the impact of the policy shock. The price changes must therefore be weighted to account for the share of trade that flows on, for example, the Texas portion of the GIWW. This was done by calculating the percentage of national trade moved on the GIWW by commodity, In other words it was derived by dividing the tonnage of a given commodity moved on the GIWW by the tonnage moved on

[29] The authorized depth is the depth at which the U.S. Army Corps of Engineers maintains the channel.
[30] The U.S. Army Corps of Engineers has set the GIWW's nominal depth at 12 feet. Recently, the channel has been allowed to assume depth of somewhat less than 12 feet, although this is irregular across the channel. The study assumed the 12 foot nominal depth as the base case. The natural forces of weather and currents cause channels to deteriorate. This means that some segments of the GIWW will become shallower than others, and vessels traversing the channel will have to be able to negotiate the shallowest portion.

all U.S. waterways. The price changes multiplied by the channel share of U.S. trade (by commodity) produce the shock for each commodity. Commodities are then shocked individually and the individual shocks are applied simultaneously to estimate the total effect of the price change for a given channel.

> The reconciliation of different commodity classification codes can be challenging when using public data. The U.S. Army Corps of Engineers, a principal source of domestic maritime trade data, uses a commodity classification system called *Lock Performance Monitoring System* (LPMS) / *Waterborne Commerce Statistics Center* (WCSC). This classification system is meant to be compatible with the *Standard International Trade Classification* (SITC) revision 3 system. The input-output tables that serve as a database for USAGE use the *North American Industry Classification System* (NAICS). Thus, commodity data provided by the USACE had to be converted to the NAICS system.

Margin Commodities

The final step in preparing a shock in USAGE is the selection of the appropriate variable to shock within the model. In this research, a change in channel depth was modeled as a technical change in the water transportation margin commodity. Technical changes to margin variables are divided into <u>deliveries</u> to production, consumption, investment, export, and government. Deliveries are the average transportation costs changes (increase or decreases) for waterborne commodities on each Texas channel and the GIWW. In this application, deliveries to the production and consumption have been modeled and deliveries to investment, export, and government have been excluded. The reasons for excluding deliveries to investment export, and government are twofold.

- First, the three channels evaluated and the GIWW in Texas are by nature inland waterways, and therefore, the primarily domestic nature of the goods movement on them obviates the need to model margin price changes on deliveries to export.
- Second, much of the cargo on these waterways is raw or low value per-ton goods. The nature of the cargo thus suggests that its direct role in investment and its deliveries to government are negligible.
- Therefore, for both theoretical and practical reasons, deliveries to investment, export, and government have been omitted.

The change in cost to the water transportation margin was assumed to result from a technological shift. As previously elaborated, as a channel is allowed to become shallower, less cargo can be loaded on the existing barge fleet. This is to ensure that the barge rides higher in the water (i.e., drafts less) and has sufficient room below the hull to avoid striking the bottom of the channel. Furthermore, whatever the barge draft, the tug boat requires an additional foot of draft for traction purposes, so the effective draft drops to seven feet in the case of an eight foot barge draft. Thus the returns to capital (with labor held constant) given the existing technology have declined, resulting in an increase in the price of barge transportation. This can be represented as a shift in the supply curve for barge transportation. It is worth acknowledging that this approach assumes that there are no long term adjustments that reflect (a) the relocation of industries because of the higher transportation costs or (b) substitution of other transportation modes (truck and rail) for the barge moves. This is considered unlikely for the waterways evaluated in this study. The petrochemical refining industry served by these channels and sections of the GIWW produces basic goods that are vital to the economy. Some of the petrochemical products produced along the channel are relatively price inelastic. Also new construction, much less relocation, is generally not an option for chemical processors and petroleum refiners. Finally, even in the case of substantial price increases, water transportation will likely remain more cost effective for the shipment of large quantities of bulk goods among regions.

Model Results

The results described in this section were derived from a set of shocks applied to the USAGE-ITC model. The[31] estimated impacts in terms of U.S GDP and real consumption, for example, can be interpreted thusly:

- the benefits that the nation realizes from maintaining the channels at their current, 12 foot authorized depth, or
- the maximum amount that the nation stands to lose by allowing the channels to silt to a depth of roughly 7 feet.

The impacts reported are thus small relative to numbers commonly reported for channel or port economic impacts. This is because the estimates reported here are not estimates of the maritime business activity along the three channels and a section of the GIWW. They are solely estimates of the efficiency gains that result from 12 feet versus 7 feet channels. The approach adopted is thus complementary to more common economic impact estimation methods. Although care should be taken in combining the two, they can each help to enhance a policymaker's understanding of the economic impact of national infrastructure.

The national economic impacts from maintaining Texas' channels at their authorized depths can be evaluated through common measures of aggregate welfare, such as real gross domestic products (GDP) and real consumption. As will be shown subsequently, channel maintenance benefits GDP. However, when output is disaggregated by sector, winners and losers emerge. For the channels evaluated and the GIWW the aggregated results, the output of farming, mining, construction manufacturing, and trade increase, while transportation of utilities and finance suffer contractions in output. Table 4.1 shows over 500 industry groups categorized into 10 economic sectors.

The output changes identified in Table 4.1 result from the changes in price to the water transportation margins of the commodities that are moved on the channels evaluated. These price changes impact the prices of final goods. Particularly interesting is the contraction in the output in the Transportation and Utilities sector. This contraction is driven by output declines in several industries. Table 4.2 shows the changes to output in the economic sectors comprising the Transportation and Utility sector by channel and for the GIWW.

[31] It has to be noted that the economic impacts of the dollars spent on dredging were not evaluated. The millions of dollars spent on dredging contribute to gains in employment and output but, the purpose of this spending is not direct job creation. These shocks that were used were intended to evaluate the impacts of dredging, not the spending itself.

Table 4.1: Changes in Output to the U.S. Economy by Sector (Thousands of 2006 Dollars)

	Chocolate Bayou	*Arroyo Colorado*	*GIWW*	*Channel to Victoria*
Farming, Fishing & Forestry	$3,306	$188	$39,612	$645
Mining, Petroleum	$1,134	$46	$13,654	$417
Construction	$1,782	$142	$22,871	$1,485
Durable Manufacturing	$1,482	($79)	$38,324	$1,509
Non Durable Manufacturing	$9,194	$886	$107,086	$6,493
Transportation & Utilities	($4,763)	($458)	($62,390)	($3,763)
Trade	$2,930	$260	$40,376	$1,669
Finance, Insurance & Real Estate	($2,177)	($76)	($28,222)	($76)
Other Services	$4,402	$821	$68,271	$2,462

Table 4.2: Percentage Output Changes to the Transportation & Utilities Sector Components

	Chocolate Bayou	*Arroyo Colorado*	*GIWW*	*Channel to Victoria*
Railroad Services	5.73E-04	6.20E-05	8.41E-03	2.80E-04
Passenger Transportation	1.61E-04	2.40E-05	2.51E-03	8.50E-05
Trucking Services	2.83E-04	3.50E-05	4.14E-03	1.76E-04
Warehousing and Storage	6.10E-05	2.90E-05	1.73E-03	4.30E-05
Water Transportation	-1.81E-02	-1.89E-03	-2.49E-01	-1.29E-02
Air Transportation	1.95E-04	3.50E-05	3.25E-03	9.00E-05
Pipeline (excluding natural gas)	2.02E-04	3.00E-05	3.40E-03	1.38E-04
Freight Forwarding	-1.80E-03	-1.72E-04	-2.48E-02	-1.16E-03
ArrangPTrans	-4.90E-04	-1.30E-05	-5.57E-03	-3.39E-04
Telecommunications	7.40E-05	9.00E-06	1.02E-03	5.20E-05
Cable and Pay TV Services	1.11E-04	1.10E-05	1.45E-03	8.00E-05
Broadcast Radio and TV	3.10E-05	3.00E-06	3.92E-04	2.00E-05
Electrical Services	2.59E-04	1.30E-05	3.35E-03	1.60E-04
Natural Gas Transportation	6.33E-04	8.70E-05	1.05E-02	2.87E-04
Natural Gas Distribution	1.97E-04	1.60E-05	2.54E-03	1.45E-04
Water Supply	1.27E-04	9.00E-06	1.52E-03	1.09E-04
Sanitary Services	2.11E-04	1.60E-05	2.80E-03	1.35E-04
Wat2	3.69E-04	9.00E-06	4.99E-03	2.12E-04
Air2	2.51E-04	1.09E-04	6.18E-03	1.07E-04

Note: The individual industries that contract explains the contraction of the Transportation and Utilities sector in Table 1.

In Table 4.2, the results are given as percentage changes in the various sectors. Although the percentage values are small, it should be stated that they have very large national coefficients, and therefore represent significant dollar values. What is important is the direction of the changes. Broadly speaking much of the sector sees gains in output. Water transportation, freight forwarding, and ArrangPTrans are the only economic sectors that contract as a result of the channel depths increasing from 7 to 12 feet. That water transportation output (demand) contracts after a technology improvement may seem counterintuitive to some readers. However, it is important to remember that it was assumed that the maintenance of a channel at its authorized depth makes barge transportation more efficient. This efficiency is realized through fewer voyages to move a given amount of cargo, which results in a change to the price of water transportation. The cost[32] was then applied within USAGE-ITC as a technological change in the margin used.

This means that when channels are maintained, there is a lower demand for barge transportation (i.e., the demand can be met at a lower level of output by the industry). Table 4.3 shows that prices tend to decline for many of the economic sectors comprising the transportation and utility sector. The decline in water transportation-barge transportation reflects the cost reductions in commodities moved on the channels evaluated.

Table 4.3: Price Effects by Sector, Expressed as a Percentage Change in Sector Output

	Arroyo Colorado	*Chocolate Bayou*	*GIWW*	*Channel to Victoria*
Railroad Services	-3.10E-05	-2.56E-04	-3.71E-03	-1.81E-04
Passenger Transportation	-1.20E-05	-3.50E-05	-9.94E-04	2.00E-06
Trucking Services	-1.10E-05	-4.70E-05	-1.05E-03	1.00E-05
Warehousing and Storage	-3.00E-06	-7.00E-06	-3.06E-04	1.00E-05
Water Transportation	-2.63E-04	-2.48E-03	-3.44E-02	-1.77E-03
Air Transportation	-2.70E-05	-7.80E-05	-2.08E-03	-8.00E-06
Pipeline (excluding natural gas)	-3.00E-05	-2.58E-04	-3.67E-03	-1.83E-04
Freight Forwarding	-3.00E-05	-2.59E-04	-3.71E-03	-1.83E-04
ArrangPTrans	-3.00E-05	-2.60E-04	-3.73E-03	-1.83E-04
Telecommunications	4.00E-06	2.30E-05	3.30E-04	1.60E-05
Cable and Pay TV Services	5.00E-06	3.20E-05	4.36E-04	1.80E-05
Broadcast Radio and TV	1.00E-05	7.70E-05	1.11E-03	5.50E-05
Electrical Services	-1.00E-06	5.20E-05	5.19E-04	1.70E-05
Natural Gas Transportation	-2.70E-05	-2.40E-04	-3.37E-03	-1.77E-04
Natural Gas Distribution	4.00E-06	1.10E-05	2.16E-04	1.20E-05
Water Supply	6.00E-06	3.90E-05	6.26E-04	-3.00E-06
Sanitary Services	-1.20E-05	-4.40E-05	-1.03E-03	-1.00E-06
Wat2	-3.20E-05	-2.74E-04	-3.93E-03	-1.93E-04
Air2	-3.10E-05	-2.65E-04	-3.82E-03	-1.85E-04

[32] The cost penalty associated with allowing the channels to silt from their authorized dept of 12 feet to 7 feet (as calculated in Chapter 3) was interpreted as the costs that will be saved if the channels are dredged from 7 feet to the authorized depth of 12 feet. Therefore, a cost reduction was specified in USAGE-ITC.

Table 4.4: Benefit Measures Attributable to Dredging (Thousands of 2006 Dollars)

	GDP	*Real Consumption*	*Investment*	*Exports*	*Imports*
GIWW	$190,136	$161,521	$39,368	$646	$19,420
Victoria	$11,347	$8,856	$2,298	$602	$959
Chocolate Bayou	$14,646	$12,545	$3,115	-$367	$1,249
Arroyo	$1,319	$1,199	$243	-$44	$45

Note: The increase in real gross domestic product is largely driven by an increase in household consumption.

Maintaining the evaluated channels and a section of the GIWW benefits the GDP. Table 4.4 shows the increase in real GDP resulting from maintaining each channel and the GIWW at its authorized depth. In each case, the benefits are positive and reflect an increase in output for the United States. GDP is defined as:

$$GDP = C + I + G + (X - M)$$

where,
C = Real consumption
I = Investment
X = Exports
M = Imports

Here, the cost savings realized from maintaining the channels and GIWW benefits household consumption, and this drives the majority of the GDP increase.

It is, however, important to emphasize that these numbers do not encompass all the benefits that these channels confer on the nation, nor does it reflect the effect on the economy were the channels to be lost entirely. These numbers only reflect the positive difference in output that the U.S. economy enjoys by not allowing the channels to deteriorate from 12 to 7 feet. Indeed, if the channels become shallower, the impact will become greater. If the channels were allowed to deteriorate in excess of the assumptions used in this research, additional vessel voyages would be affected, and operational practices would have to be further altered to allow for the navigation of the shallower channels. The increase in the cost of barge transportation as channel depth approaches the limit of navigability is likely to be nonlinear. As the channels approach that limit, some of the assumptions that underlie the cost calculations in Chapter 3 will probably become untenable and transportation costs could increase substantially.

4.2 Texas Deep Draft Channels

Texas deep draft channels handle a significant amount of U.S. international trade. The Port of Houston routinely ranks among the largest U.S. ports in tonnage and container handling. The Ports of Beaumont and Corpus Christi handle large amounts of cargo in their own right and also handle large amounts of military equipment that support U.S. military activities abroad. More broadly, Texas' deep draft channels facilitate the trade and processing of large amounts of oil and chemicals. They facilitate waterborne access to the Texas Gulf Coast, which is home to a significant portion of the United States' chemical and petroleum refining assets.

The research team evaluated eight Texas deep draft channels using the USAGE-ITC model. These are the channels associated with the Port of Brownsville, Port of Corpus Christi, Port Freeport, Port of Galveston, Port of Houston, Port Lavaca, the Sabine-Neches Waterway—associated with the Port of Beaumont, Port Arthur and Port of Orange—and the Port of Texas City. As with Texas' shallow draft ports, the research team estimated the cost penalties that would be realized by allowing each channel to deteriorate by a specified amount. In practice, estimating these costs differed from the process used to estimate the shallow draft cost penalties. This is primarily due to the complexity of international shipping at these ports. Readers interested in details of the estimation method should refer to Appendix D of this report where calculations for the Port of Brownsville are given.

The cost data used in this report were based on an analysis of shipping affected by allowing the channel depth to decrease by a given amount. For example, if a channel has an authorized depth of 40 feet and it deteriorates to 35 feet deep, a portion of ships using the channel will have to carry fewer tons of cargo to allow them to reduce their draft. The cost of operating the vessel is broadly fixed, so moving less cargo increases the average cost for moving each ton of cargo. This raises the cost of serving the port because it prevents the operation of vessels with better economies of scale and lower average operating costs. Over the long term, industries may adjust to deterioration in channel depth. The cargo may also be shifted to other ports, or shippers may use different vessels, or even modes. To keep the problem tractable, these factors have been held constant; that is, it has been assumed that demand will remain fixed, which appears to be a reasonable assumption over the short and medium term.

The incorporation of large amounts of international trade into the analysis means that a different approach must be taken to evaluate each deep draft channel within USAGE-ITC. While margin variables are well-suited to the evaluation of domestic trade, the data on which they rely are only collected on voyages that begin at a port of entry or end at a port of exit. In other words, the water transportation margin commodity that is part of the production of many final goods does not include the value of international water transportation for imported goods. Moreover, imports of a commodity are treated separately from domestic production, meaning that the shock would be applied only to domestic output. Shocking a commodity via its water transportation margin commodity with a price change calculated on the basis of its international shipment would thus produce an erroneous result because it would be calculated on the basis of an incorrect volume of the commodity. More fundamentally, imports have a negative effect on GDP, and this would further compound the folly of shocking margin commodities in an analysis examining imports and maritime trade.

Analyses of water transportation impacts on the U.S economy and international trade were instead applied directly to import and export prices. Imports in USAGE-ITC are described as the total value of imports based on cost, insurance, and freight (c.i.f.) prices, meaning that the total value of imports includes the price of shipment. If the aggregate cost benefit to the price of shipping a commodity is known, it can be used to calculate the percentage change in the aggregate price of an imported commodity. Export prices must be treated differently. Export prices are closely linked to domestic prices. Exports can, therefore, be affected through properly designed shocks on domestic prices, provided that they are weighted so that they only apply to commodities passing through Texas ports. The shocks applied to USAGE-ITC are derived from the total cost benefit of maintaining a channel, deflated to 2002 dollars.[33] Commodity tonnage is divided into imports and domestic and export cargo. This cost is allocated to each commodity

[33] This is because the values in the USAGE-ITC database are 2002 dollars.

that a port handles in proportion to its percentage of total port tonnage. Each commodity is associated with a dollar benefit, and the sum of the benefits accorded to all commodities at a port is equal to the total estimated cost benefit from channel maintenance. Each commodity cost benefit is then divided by either its total 2002 sales, or the total 2002 c.i.f. imports of the commodity. In this way, researchers are able to express the cost benefit as a percentage of total national sales or total imports.

Prices in USAGE-ITC must be altered indirectly, generally through microeconomic mechanisms of varying specificity. These mechanisms include tariffs, changes in preferences and supply and demand shifts of various sorts. The most direct approach to apply the cost benefits to the commodities that are handled at each port is to shift the supply curve for that commodity. For each commodity that a port handles, the price of that commodity is lowered by its cost benefit as a percentage of total national sales (or imports). In USAGE-ITC, this is occurring in general equilibrium across all markets. These results are quantified in the results section of this chapter.

4.2.1 Results

Calculating the deep water Texas port channel costs was described in Chapter 3 of this report and the results given in Table 3.3. These costs were then transformed, as described in this chapter, into inputs for the various commodity groups selected for the Texas ports in USAGE-ITC, weighted by the Texas share of the national market for each commodity. The results are given in Table 4.5. The table presents impacts for the U.S GDP, household consumption, and investment (less government investment). At the time when the model was run to give these data, the U.S GDP was $13.20 trillion, household consumption was $9.23 trillion, and investment $2.21 trillion.

Table 4.5: Deep Draft Impacts

	GDP	*Consumption*	*Investment*
Brownsville	$2,507	$2,860	$641
Corpus Christi	$6,861	$9,225	$1,657
Port Freeport	$7,785	$12,453	$2,474
Galveston	$2,771	$2,491	$0
Houston	$792,606	$937,670	$178,901
Port Lavaca - Matagorda	$3,167	$3,598	$685
Sabine-Neches	$247,401	$314,648	$63,537
Texas City	$27,841	$42,525	$8,505

The figures represent the impact of allowing a 5 foot silting of the main channel but the calculations are different because the input data for Port Freeport, Houston, Sabine-Neches, and Texas City came from the Martin and Associates studies while the rest were calculated as described in Chapter 3 of this report. It is interesting to note the wide magnitude of effect and clearly this is a topic that deserves further inquiry. Broader understanding of the USAGE-ITC model capabilities, a consistent treatment of transportation cost effects of siltration and a better understanding of how to efficiently (and equitably) translate these into the shocks used in the modeling are all areas for future research. It is believed that this attempt to model a GDP impact is the first of its type in U.S port applications and is provides additional financial impacts to those determined by the traditional input-output port impact methods. It is unlikely to be the last as port authorities attempt to capture the full economic impact of their operations, which in many cases stretch beyond city, county and state boundaries.

In the next chapter, the researchers provide information on the smaller Texas ports that, while having an economic impact, had not chosen to sponsor a full input-output evaluation at the time this study was undertaken.

Chapter 5. Local and Regional Texas Port Economic Impacts

The CTR research team used IMPLAN Input-Output modeling software to estimate the local and regional economic impact of five Texas seaports:

- Port of Galveston
- Port of Harlingen
- Port of Port Isabel
- Port Mansfield, and
- Port of Palacios

In addition, data is given for the Port of Orange, as requested by the Texas Ports Association. It was not possible to undertake an IMPLAN analysis because Hurricane Ike hit shortly before a port visit was planned to collect input data. It is recommended that any analysis be delayed until 2009 while the severe damage to the region is addressed.

The direct impacts were estimated based on surveys of port users. The research team surveyed businesses and port users at each port. Direct measures of business activity were collected, including sales, employment, and tax information. Attitudes toward what comprised confidential data varied by business, with many businesses providing incomplete data. When possible, the data obtained was verified against publicly available databases, such as tax, revenue, and employment figures available from the Texas Workforce Commission. The survey and modeling approach are detailed in Appendix F. This chapter describes the salient findings of the surveys and modeling effort.

5.1 Port of Galveston

The Port of Galveston is located at the mouth of Galveston Bay in Galveston County. Although the port is best known for its cruise industry, it also handles many types of cargo, including dry and liquid bulk, break-bulk, roll-on/roll-off cargo, and refrigerated and project cargoes.[34,35]

The Port of Galveston serves southeast Texas, including Galveston County, Harris County, Fort Bend County, and Brazoria County. It also handles cargo destined for states neighboring Texas and the Midwest region. The Port of Galveston facilitates trade with countries that include Mexico, Guatemala, Panama, Columbia, Venezuela, Brazil, the Dominican Republic, Spain, Italy, Egypt, Israel, Turkey, Bulgaria, Belgium, England, Germany, Saudi Arabia, United Arab Emirates, Kuwait, Singapore, and China.

In 2006, the Port of Galveston handled 6,217,668 tons of cargo (compared to 4,550,035 tons in 2005), while 616,939 passengers (compared to 532,241 passengers in 2005) embarked on cruises departing from the port in 2006. Therefore, both cargo handling and the cruise industry are growing at Galveston.

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[34] For example, the Port of Galveston is an exporter of bulk grains, containers, machinery, vehicles, liner board and paper, carbon black, and light fuels.

[35] Port of Galveston, “The Port of Galveston,” 2007, <http://www.portofgalveston.com/index.shtml> (11 July 2007)

The following tables illustrate the estimated local and regional economic impacts of the Port of Galveston using IMPLAN. As shown in Table 5.1, the model calculated that approximately 13,367 jobs were created by businesses that depend on the port. These jobs provided approximately $727 million in labor income. The port-dependant businesses also generated $2.25 billion in revenues in 2006 and $190.4 million in local, state, and federal taxes.

Table 5.1: Port of Galveston Economic Impacts

Employment	**13,367**
Direct	3,326
Indirect	3,794
Induced	6,247
Labor Income	**727,515,143**
Direct	212,592,013
Indirect	229,653,920
Induced	285,269,215
Output	**2,245,772,546**
Direct	985,988,454
Indirect	515,937,234
Induced	743,846,762
Taxes	**190,386,077**
State and Local Taxes	86,258,823
Federal Taxes	104,127,254

The transportation and warehousing sector were responsible for the largest economic impacts both in terms of output (see Table 5.2) and employment (see Table 5.3). This sector alone accounted for over 45 percent of the total revenues (i.e., output) generated by businesses dependant on the Port of Galveston. Table 5.3 also shows that the transportation and warehousing sector generated over 27 percent of the jobs at port-dependant businesses.

Table 5.2: Output by Industrial Sector in 2006 Dollars

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	0	122,594	864,807	987,401
Mining	3,501,118	9,548,256	36,581,744	49,631,116
Utilities	0	7,447,691	19,759,592	27,207,282
Construction	0	3,668,232	96,347,272	100,015,504
Manufacturing	63,657,548	48,302,368	88,299,440	200,259,360
Wholesale trade	4,784,983	22,217,706	35,521,108	62,523,796
Transportation & warehousing	861,804,928	153,049,616	18,409,294	1,033,263,936
Retail trade	1,694,423	2,724,245	59,239,076	63,657,744
Information	2,786,879	23,698,140	19,658,750	46,143,768
Finance & insurance	2,182,816	68,352,720	46,295,888	116,831,424
Real estate & rental	0	27,589,472	35,084,760	62,674,232
Professional—scientific & tech svcs	250,985	68,440,120	46,530,668	115,221,776
Management of companies	0	10,964,929	3,318,636	14,283,565
Administrative & waste services	17,451,868	38,717,572	16,506,491	72,675,928
Educational services	0	944,499	5,661,575	6,606,074
Health & social services	0	6,318	52,031,600	52,037,916

Arts, entertainment & recreation	1,138,613	1,750,561	5,719,982	8,609,156
Accommodation & food services	11,445,880	6,334,650	25,938,964	43,719,492
Other services	0	9,481,142	26,076,188	35,557,332
Government & non NAICs	15,288,414	12,576,403	106,000,928	133,865,744
Total	**985,988,454**	**515,937,234**	**743,846,762**	**2,245,772,546**

Table 5.3: Employment Impacts by Industry Sector

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	0.0	3.1	17.5	20.6
Mining	15.7	12.7	99.1	127.4
Utilities	0.0	5.0	13.6	18.6
Construction	0.0	35.7	790.9	826.6
Manufacturing	396.9	126.3	165.1	688.4
Wholesale trade	28.0	129.9	207.7	365.6
Transportation & warehousing	2,087.9	1,434.9	171.8	3,694.6
Retail trade	27.5	43.4	943.4	1,014.3
Information	11.3	97.6	59.5	168.4
Finance & insurance	15.5	357.2	226.7	599.3
Real estate & rental	0.0	138.0	176.3	314.3
Professional—scientific & tech svcs	1.9	541.2	382.4	925.5
Management of companies	0.0	94.2	28.5	122.7
Administrative & waste services	148.6	466.8	309.0	924.4
Educational services	0.0	13.4	98.6	112.0
Health & social services	0.0	0.1	590.9	590.9
Arts, entertainment & recreation	16.1	32.0	114.5	162.6
Accommodation & food services	217.6	117.9	484.8	820.2
Other services	0.0	78.7	437.1	515.8
Government & non NAICs	358.9	65.6	930.1	1,354.6
Total	**3,325.7**	**3,793.9**	**6,247.3**	**13,367.0**

5.2 Port of Harlingen

The Port of Harlingen is located approximately four miles east of the city of Harlingen in Cameron County on the Arroyo Colorado channel. The channel is maintained at a depth of 12 feet and a width of 125 feet.[36] It links the agricultural industries of Cameron County to the Gulf Intra-Coastal Waterway and the Gulf of Mexico.

The Port of Harlingen has a 650-ft dry cargo wharf, a 100-ft dry bulk wharf, and five smaller docks.[37] The construction of a warehouse facility that will be leased to local port users is currently in the planning stages. The port facilitates the trade of bulk cargo and petroleum between areas in South Texas and Mexico.[38] In 2005, the Port of Harlingen moved 946,963 tons of cargo, largely sugar and chemicals.[39] While sugar is among the largest exports, the port's principal imports are petroleum, cement, sand, and fertilizer.

The following tables summarize the estimated local and regional economic impacts of the Port of Harlingen using IMPLAN. The model estimated that 88 jobs were created by businesses

[36] Port of Harlingen Authority, "Location," n.d., <http://www.portofharlingen.com/Location.htm>.
[37] Port of Harlingen Authority, "Facilities," n.d., <http://www.portofharlingen.com/Facilities.htm>.
[38] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-13.
[39] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-13.

dependent on the Port of Harlingen in 2006. These jobs provided $3.7 million in labor income. Port-dependant businesses generated $19.4 million in revenues and $888,503 in local, state, and federal taxes according to the IMPLAN analysis, as summarized in Table 5.4.

Table 5.4: Port of Harlingen Economic Impacts

Employment	**88**
Direct	40
Indirect	24
Induced	24
Labor Income	**3,701,471**
Direct	2,225,774
Indirect	825,018
Induced	650,679
Output	**19,349,446**
Direct	14,965,174
Indirect	2,469,991
Induced	1,914,280
Taxes	**888,503**
State and Local	422,275
Federal	466,228

The manufacturing sector created the most significant economic impact in terms of both output (see Table 5.5) and employment (see Table 5.6). This sector generated over 70 percent of the total output from port-dependent businesses and over 45 percent of the jobs at businesses dependant on the Port of Harlingen.

Table 5.5: Output by Industrial Sector in 2006 Dollars

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	0	6,979	13,031	20,011
Mining	0	96,257	4,931	101,188
Utilities	0	39,769	25,721	65,490
Construction	0	61,334	13,697	75,031
Manufacturing	13,641,761	286,991	96,996	14,025,748
Wholesale trade	0	343,168	89,965	433,133
Transportation & warehousing	1,323,413	613,956	50,047	1,987,416
Retail trade	0	22,058	322,581	344,639
Information	0	63,908	66,948	130,855
Finance & insurance	0	161,391	132,547	293,939
Real estate & rental	0	123,895	81,994	205,889
Professional—scientific & tech svcs	0	274,287	62,308	336,595
Management of companies	0	29,146	1,767	30,913
Administrative & waste services	0	103,761	31,529	135,290
Educational services	0	216	13,663	13,879
Health & social services	0	188	324,965	325,153
Arts, entertainment & recreation	0	3,788	24,646	28,434
Accommodation & food services	0	40,095	134,361	174,456
Other services	0	121,260	110,829	232,088
Government & non NAICs	0	77,545	311,755	389,300
Total	**14,965,174**	**2,469,991**	**1,914,280**	**19,349,446**

Table 5.6: Employment Impact by Industrial Sector

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	0.0	0.1	0.3	0.4
Mining	0.0	0.2	0.0	0.2
Utilities	0.0	0.1	0.1	0.2
Construction	0.0	1.0	0.2	1.1
Manufacturing	38.5	1.0	0.4	40.0
Wholesale trade	0.0	3.6	0.9	4.5
Transportation & warehousing	1.8	6.7	0.6	9.1
Retail trade	0.0	0.4	6.3	6.7
Information	0.0	0.4	0.3	0.7
Finance & insurance	0.0	1.1	0.9	2.0
Real estate & rental	0.0	0.6	0.6	1.2
Professional—scientific & tech svcs	0.0	3.1	0.7	3.8
Management of companies	0.0	0.2	0.0	0.2
Administrative & waste services	0.0	2.6	0.7	3.2
Educational services	0.0	0.0	0.3	0.3
Health & social services	0.0	0.0	5.1	5.1
Arts, entertainment & recreation	0.0	0.1	0.6	0.7
Accommodation & food services	0.0	0.9	3.0	3.9
Other services	0.0	1.5	2.7	4.2
Government & non NAICs	0.0	0.4	0.3	0.7
Total	**40.4**	**24.1**	**23.9**	**88.3**

The Port of Harlingen's economic impact is relatively modest compared to the other analyzed ports. This is in part due to the fact that the port does not serve labor intensive industries. However, the Port is very profitable with capital reserves and the ability to self-finance client services and facilities.

5.3 Port of Port Isabel (The Port Isabel-San Benito Navigation District)

The Port of Port Isabel is located approximately 35 miles southeast of Harlingen in Cameron County. Located near South Padre Island, the port is in an important tourism area. Port Isabel has traditionally served various seafood processing, concrete mix, and boat construction and repair companies.[40] Although the port has traditionally supported offshore exploration, substantial recent petroleum discoveries in the Gulf of Mexico have made Port Isabel the closest deepwater port to these major gulf petroleum deposits and have therefore boosted its attractiveness for use by oil service vessels (OSVs). This has initiated major changes at the port as it prepares to support the exploration and extraction operations in the gulf. The economic impacts reported in this document will thus be outdated by the publication date of this report if the anticipated offshore exploration activities materialize. Also, a shift towards supporting oil services will likely change the dimensions of Port Isabel's international trade. However, currently Port Isabel facilitates trade to and from the Rio Grande Valley, as well as with Honduras, El Salvador, Guatemala, and Belize.[41]

The economic analysis conducted in this study focused on the economic impacts generated by the fishing and shrimping, oil services, food processing and preparation, concrete manufacturing and sales, boat building and repair, and paper industries that are supported by Port Isabel currently. Each of the port-dependant companies, with the exception of the shrimping sector, were contacted and surveyed. The shrimping sector in South Texas has contracted recently as a result of rising costs and falling prices for Gulf shrimp. Because of the disaggregated nature of the shrimping sector and the difficulty in identifying and classifying different levels of activity, it was decided to use the Port Director's estimate that the shrimping sector employs 300 full time people in IMPLAN.

The following tables show the estimated local and regional economic impacts of Port Isabel using IMPLAN. This model estimated that businesses dependant on Port Isabel generated 948 jobs in 2006, which provided $23.4 million in labor income. Table 5.7 demonstrates that these businesses also generated approximately $85.6 million in output and $5.83 million in local, state, and federal taxes.

[40] Bates, Valerie D., "Community Profile," 2007, <http://www.portisabel-texas.com/info/profile1.html>.
[41] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-16.

Table 5.7: Port Isabel Economic Impacts

Employment	**948**
Direct	605
Indirect	189
Induced	154
Labor Income	**23,376,819**
Direct	14,030,854
Indirect	5,159,666
Induced	4,186,298
Output	**85,602,367**
Direct	58,176,850
Indirect	15,109,757
Induced	12,315,759
Taxes	**5,830,209**
State and Local	2,689,589
Federal	3,140,621

The manufacturing sector was responsible for generating the most output/revenues (see Table 5.8), while the agriculture, forestry, fishing, and hunting sector created the most jobs (see Table 5.9). The manufacturing sector was responsible for over 50 percent of the revenues from businesses dependant on the Port. The agriculture, forestry, fishing, and hunting sector generated more than 37 percent of the port-dependant jobs in Port Isabel.

Table 5.8: Output by Industrial Sector in 2006 Dollars

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	5,869,854	1,047,622	83,841	7,001,316
Mining	10,800,038	120,138	31,725	10,951,902
Utilities	0	254,589	165,487	420,076
Construction	0	773,086	88,123	861,209
Manufacturing	41,237,784	2,364,192	624,055	44,226,032
Wholesale trade	269,174	3,183,387	578,804	4,031,365
Transportation & warehousing	0	2,698,371	321,991	3,020,362
Retail trade	0	287,196	2,075,345	2,362,541
Information	0	364,154	430,721	794,875
Finance & insurance	0	765,930	852,743	1,618,673
Real estate & rental	0	490,355	527,580	1,017,935
Professional—scientific & tech svcs	0	717,899	400,871	1,118,770
Management of companies	0	232,118	11,369	243,487
Administrative & waste services	0	354,633	202,851	557,484
Educational services	0	1,458	87,898	89,356
Health & social services	0	754	2,090,823	2,091,577
Arts, entertainment & recreation	0	103,681	158,566	262,247
Accommodation & food services	0	175,228	864,382	1,039,609
Other services	0	893,703	713,043	1,606,747
Government & non NAICs	0	281,263	2,005,539	2,286,802
Total	**58,176,850**	**15,109,757**	**12,315,759**	**85,602,367**

Table 5.9: Employment Impacts by Industrial Sector

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	300.0	52.4	1.7	354.1
Mining	97.8	0.6	0.1	98.5
Utilities	0.0	0.7	0.6	1.2
Construction	0.0	9.6	1.1	10.7
Manufacturing	204.7	10.9	2.8	218.4
Wholesale trade	2.8	33.1	6.0	41.9
Transportation & warehousing	0.0	30.0	3.7	33.7
Retail trade	0.0	5.6	40.5	46.1
Information	0.0	2.2	2.2	4.3
Finance & insurance	0.0	5.3	5.8	11.1
Real estate & rental	0.0	3.3	3.6	6.9
Professional—scientific & tech svcs	0.0	7.3	4.7	12.0
Management of companies	0.0	1.9	0.1	2.0
Administrative & waste services	0.0	7.3	4.3	11.7
Educational services	0.0	0.0	2.1	2.1
Health & social services	0.0	0.0	32.5	32.5
Arts, entertainment & recreation	0.0	2.4	3.8	6.1
Accommodation & food services	0.0	3.9	19.3	23.2
Other services	0.0	10.9	17.2	28.2
Government & non NAICs	0.0	1.4	1.8	3.2
Total	**605.3**	**188.8**	**153.8**	**947.9**

5.4 Port Mansfield

Port Mansfield is located in South Texas approximately 31 miles northeast of Harlingen in Willacy County[42] and is one of the smaller Texas ports. In the past it had been a base for gulf oil service operations. However, today it is primarily a fishing community that attracts vacationers from around the state and beyond. Fishing at Port Mansfield takes one of two forms; i.e., shallow water bay fishing and deep water offshore fishing. A limited number of visitors to the community bring their own boats and fishing gear, but the majority employ local guides with boats to transport them to the best fishing areas. More than 50 fishing guides offer instruction and transportation for both bay and offshore fishing in Port Mansfield. This is a significant source of income to a community with less than 500 year-round residents. The port also attracts a small number of non-fishing visitors who may purchase or lease property in the area. Two RV facilities accommodate a number of so-called "winter Texans," visitors from colder states or areas in Texas that spend colder months in temperate south Texas.

In recent years, the channel leading to the offshore fishing has silted up, creating hazardous conditions for fishermen and inhibiting fishing guides from taking advantage of lucrative offshore fishing that typically requires deeper draft boats. Some fishing guides have at times damaged their boats, and at least one guide has relocated to Port Isabel because the channel has become too shallow for his boat.

Until recently, bay fishing has remained feasible and a source of income to the local community. However, in recent months the mouth of the port (in addition to the channel that provides access to the Gulf) has silted to the point that it threatens to close the port. Residents of Port Mansfield have raised funding and leased a dredging barge that is being operated by local labor. This should mitigate the most immediate threat to the community, i.e., an imminent closure of the port due to siltation. However, it does not restore safe access to the Gulf, and it remains to be seen whether this arrangement can be maintained over the long term.

Businesses that are dependent on Port Mansfield include commercial fishing, real estate and property management, hotels and lodging, restaurants and catering, boat storage, boat repair, and fishing supplies.

The following tables illustrate the local and regional economic impacts of the port-dependant businesses in Port Mansfield. The IMPLAN model estimated that 167 jobs were created as a result of the port (see Table 5.10). These jobs in turn generated \$5.58 million in labor income. The port-dependent businesses also created approximately \$11.32 million in revenues and \$1.17 million in local, state, and federal taxes.

[42] City-Data.com, "Port Mansfield, Texas," 2007, <http://www.city-data.com/city/Port-Mansfield-Texas.html>.

Table 5.10: Port Mansfield Economic Impacts

Employment	**167**
Direct	102
Indirect	9
Induced	56
Labor Income	**5,578,189**
Direct	3,580,277
Indirect	278,384
Induced	1,719,527
Output	**11,324,814**
Direct	6,248,918
Indirect	821,928
Induced	4,253,967
Taxes	**1,175,257**
State and Local	591,604
Federal	583,653

As expected, the agriculture, forestry, fishing, and hunting sector contributed the most significant economic impacts, generating over 28 percent of the revenues (Table 5.11) and more than 30 percent of the jobs (Table 5.12) in Port Mansfield.

Table 5.11: Port Mansfield Output by Industrial Sector in 2006 Dollars

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	3,184,814	6,090	26,498	3,217,402
Mining	0	4,382	23,048	27,430
Utilities	0	24,512	55,267	79,778
Construction	0	125,419	220,482	345,902
Manufacturing	40,000	55,213	223,561	318,774
Wholesale trade	0	53,432	174,984	228,416
Transportation & warehousing	0	76,304	111,302	187,605
Retail trade	163,901	23,875	566,657	754,434
Information	0	51,578	130,985	182,563
Finance & insurance	0	58,645	244,552	303,197
Real estate & rental	966,924	87,602	161,274	1,215,801
Professional—scientific & tech svcs	0	68,119	141,926	210,045
Management of companies	0	3,058	3,389	6,447
Administrative & waste services	0	86,111	78,947	165,058
Educational services	0	146	23,810	23,956
Health & social services	0	21	559,678	559,699
Arts, entertainment & recreation	93,707	16,183	42,080	151,969
Accommodation & food services	1,799,573	15,706	237,892	2,053,170
Other services	0	24,748	203,150	227,898
Government & non NAICs	0	40,784	1,024,485	1,065,269
Total	**6,248,918**	**821,928**	**4,253,967**	**11,324,814**

Table 5.12: Port Mansfield Employment Impacts by Industrial Sector

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	51	0.2	0.5	51.7
Mining	0	0	0.1	0.1
Utilities	0	0.1	0.2	0.3
Construction	0	1.5	2.4	4
Manufacturing	0.3	0.3	1	1.6
Wholesale trade	0	0.6	1.8	2.4
Transportation & warehousing	0	1	1.3	2.3
Retail trade	4.6	0.5	11.1	16.1
Information	0	0.3	0.7	1
Finance & insurance	0	0.4	1.7	2.1
Real estate & rental	6.3	0.5	1.1	7.9
Professional—scientific & tech svcs	0	0.8	1.7	2.4
Management of companies	0	0	0	0.1
Administrative & waste services	0	1.5	1.7	3.3
Educational services	0	0	0.6	0.6
Health & social services	0	0	8.8	8.8
Arts, entertainment & recreation	1.9	0.4	1	3.3
Accommodation & food services	37.8	0.3	5.3	43.4
Other services	0	0.4	4.7	5.2
Government & non NAICs	0	0.2	10.5	10.7
Total	102	9	56	167

5.5 Port of Palacios

The Port of Palacios is located approximately 110 miles south of Houston in Matagorda County. Traditionally, shrimping had been the most important industry at the Port of Palacios. Although the shrimping industry in Texas has declined because of rising costs and falling shrimp prices, as many as 300 shrimp and oyster boats continue to operate in Palacios. In Texas, the Port of Palacios is the second largest shrimping port, following the combined total of the Ports of Brownsville and Port Isabel.[43] In 2005, the shrimpers at the Port of Palacios caught 12.1 million tons of shrimp. These shrimpers work with a number of local shrimp processing and packaging companies.[44] Palacios also offers recreational marina facilities and tourist accommodations.

Traditionally, the Port of Palacios had a significant ship repair and service industry, which served the shrimp fleet. As the shrimp fleet decreased in size, some facilities have been converted to serve a growing barge and boat building industry.

The following tables provide the estimated local and regional economic impacts of the Port of Palacios using IMPLAN. This model estimated that businesses dependent on the Port of Palacios generated 658 jobs, which created $10.91 million in labor income in 2006. As shown in Table 5.13, these businesses also created approximately $41.22 million in revenues and $2.08 million in taxes.

[43] Hart Distributing, "The Port of Palacios," n.d., <http://www.portofpalacios.com/pp.htm>.
[44] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-21.

Table 5.13: Port of Palacios Economic Impacts

Employment	**658**
Direct	541
Indirect	74
Induced	43
Labor Income	**10,913,066**
Direct	7,948,474
Indirect	1,833,596
Induced	1,130,997
Output	**41,223,913**
Direct	31,059,218
Indirect	6,075,649
Induced	4,089,045
Taxes	**2,081,315**
State and Local	791,191
Federal	1,290,125

The manufacturing sector generated the largest revenues (see Table 5.14) and the agriculture, forestry, fishing, and hunting sector created the most jobs (see Table 5.15) in the Port of Palacios in 2006. The manufacturing sector generated nearly 60 percent of the total revenues generated by businesses dependant on the Port of Palacios. The agriculture, forestry, fishing, and hunting sector generated nearly 70 percent of the jobs that are dependent on the Port of Palacios.

Table 5.14: Output by Industrial Sector in 2006 Dollars

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	8,287,367	811,168	57,668	9,156,204
Mining	0	15,893	5,692	21,585
Utilities	0	264,045	163,086	427,130
Construction	0	873,879	33,268	907,147
Manufacturing	22,062,652	1,848,631	352,123	24,263,406
Wholesale trade	0	523,125	80,038	603,163
Transportation & warehousing	0	388,423	56,144	444,567
Retail trade	0	105,753	700,505	806,258
Information	0	81,543	79,092	160,635
Finance & insurance	0	186,285	206,465	392,749
Real estate & rental	0	116,120	93,336	209,456
Professional—scientific & tech svcs	0	221,594	64,736	286,330
Management of companies	0	57,246	2,458	59,704
Administrative & waste services	0	132,661	63,585	196,246
Educational services	0	520	42,329	42,849
Health & social services	0	20	576,881	576,902
Arts, entertainment & recreation	0	45,429	33,850	79,279
Accommodation & food services	709,199	57,072	319,157	1,085,428
Other services	0	239,087	246,238	485,324
Government & non NAICs	0	107,156	912,394	1,019,550
Total	**31,059,218**	**6,075,649**	**4,089,045**	**41,223,913**

Table 5.15: Employment Impacts by Industrial Sector

	Direct	Indirect	Induced	Total
Agriculture, forestry, fish & hunting	418	36	1	456
Mining	0	0	0	0
Utilities	0	0	0	1
Construction	0	9	0	9
Manufacturing	115	6	1	121
Wholesale trade	0	4	1	5
Transportation & warehousing	0	4	1	5
Retail trade	0	2	12	14
Information	0	1	0	1
Finance & insurance	0	1	1	2
Real estate & rental	0	1	1	2
Professional—scientific & tech svcs	0	2	1	3
Management of companies	0	0	0	0
Administrative & waste services	0	2	1	3
Educational services	0	0	1	1
Health & social services	0	0	8	8
Arts, entertainment & recreation	0	1	1	2
Accommodation & food services	8	1	7	16
Other services	0	3	5	8
Government & non NAICs	0	1	1	1
Total	**541**	**74**	**43**	**658**

5.6 Port of Orange

The port, which has a long history going back over 100 years, has two economic roles; first as the Port Authority for the Orange County Navigation and Port District (created in 1953) and a second as a Industrial Development Authority, facilitating beneficial economic impacts in the region. It is located on the Sabine-Neches waterway and is linked to the "Golden Triangle" ports of Port Arthur, Beaumont and Sabine Pass – an area that has become strategically more important to Texas ports growth since 2003. Access to the Gulf Intracoastal Waterway is good and a container terminal facility is currently being evaluated on port property. It has handled an annual tonnage of around 800,000 since 2001 and traditionally has acted as a successful landlord port, complementing activities at larger ports on the Sabine-Neches channel. In 2003, the Port Director described it as an "overflow" port for the ports of Beaumont and Port Arthur, supplementing their operations by offering additional storage when their own facilities were at capacity. Table 5.16 gives the principal activities and throughput for 2001-4, and describes facilities which are likely to change significantly in the immediate future as the port grows.

Table 5.16: Port of Orange

Principal Activities and Products:

- The Port facilities and equipment include four berths with a total of 2,300 feet of docking space at a depth of 30 feet, a grain elevator and bagging facility, and eight warehouses.
- The Port docks are currently used for layberth and ship repair. The docks are regularly used by MARAD, which is a division of the US Department of Transportation, to service, repair, and maintain the military ready reserve fleet.

	2001	2002	2003	2004
Cargo (tons)	798,000	764,000	825,000	609,000
Revenues*	$2,260,521	$1,889,001	$1,990,561	$1,969,975

*Port revenues

Table 5.17 gives the channel depth for the port and provides port traffic, in thousand short tons, for the period 1995-2004.

Table 5.17: Orange, TX (Sabine River) (Part of Waterway)

Section included: Mouth Neches River to mouth Sabine River, thence upstream to Old U.S. Highway 90, about 16 miles; Adams Bayou, 1.6 mile; Cow Bayou, 7.2 miles. Maintained Depth: 27 feet except channel around Orange Harbor Island, 20 feet; Adams Bayou, 9 feet; Cow Bayou, 8 feet. Tidal range to 3 feet at mean higher high water.

Comparative Statement of Traffic (thousand short tons)

Year	Total	Year	Total	Year	Total	Year	Year
1995	693	1998	756	2001	798	2004	609
1996	616	1999	873	2002	764		
1997	691	2000	681	2003	825		

Table 5.18 gives the key product groups at the port which comprise petroleum, chemicals, aggregates, and cement/concrete moving over domestic routes.

Table 5.18: Freight Traffic, 2004 (Thousand Short Tons)

Commodity	Grand Total	Foreign Inbound	Total	Domestic Receipts	Internal Shipments
Total, all commodities	609	3	606	434	172
Comprising:					
Total petroleum and petroleum products	217	--	217	120	98
Total chemicals and related products	144	--	144	73	71
Total crude materials, inedible except fuels	127	1	126	126	
Total primary manufactured goods	121	2	119	115	3

Currently, warehouse space is leased to a plastics company, but has also been used to store lumber in the past. Neches Marine operates a topside repair facility within port property and is planning to use a rail system to bring barges out of the water to facilitate full repair and maintenance activities. Job creation at the port picked up after 2005, following the storing of vessels and the first stage of rehabilitating the Union Pacific link to port property. The refurbished rail line was also complemented by an improved road link to the port, built by an oil company at a cost of $300,000. Finally, Tubal-Cain is leasing a dry dock from an operator in Channelview which will sit in 24 acres at the port. The company performs mechanical and electrical repairs, as well as fabrication for ocean-going barges of the type used to service deep water Gulf oil rigs. Several other initiatives are being pursued by the Port Director and it is likely that in the near future an input-output evaluation of the economic benefits of the port will be warranted. IMPLAN use should be postponed at least until 2009 since the Port, and its hinterland, were severely damaged by Hurricane Ike.

Chapter 6. Container Forecast for Texas Terminals

The project required that a forecast be made of container growth in the Houston ship channel over the next 20 years—a similar period to some of the TxDOT planning cycles for highway investment. Forecasts of transportation demand in general are risky and frequently problematic. Not only are data hard to come by and future operations difficult to time but expectations on the part of the various players may exert inappropriate biases into the work. Recent, extensive work (see Box 1) examining 210 projects in 14 nations worth over $59 billion indicates that many public works projects are overestimated (17). For example, 9 out of 10 passenger rail projects overestimated demand by an average of 106 percent. Are container forecasts any easier to predict?

Box 1. How Accurate are Demand Forecasts?

Road project differentials between actual and forecasted traffic exceed +/- 20 percent, while for rail projects it exceeds +/-100 percent. The study data show that forecasts have not become more accurate over the 30 year period studied, despite claims to the contrary by forecasters.

Source: Ref 17

The answer, it would seem, is no. Several years ago a U.S Chamber of Commerce study, undertaken by TranSystems—a respected port terminal design and operations consulting company—used an econometric model to predict container volumes through U.S port terminals (18). The work, when presented, did not include specific container terminal forecasts and mention was made only of aggregate U.S volumes doubling or tripling over the twenty-year period. In 2006, presentations made by senior U.S. DOT staff addressing the need for a National Freight Policy in the U.S cited container forecasts derived from a simple trend analysis of container growth in the 1990s extended out to 2020 (19). The results for individual ports were significant, for example they suggested that over 60 million TEUs could be processed by terminals in Southern California by 2020. Most planners agree that such a figure could only be possible in the (unlikely) event that completely new, environmentally-friendly and highway-free, region-wide systems were employed to process the boxes. Furthermore, because the forecast only used existing 1990s terminals, the contribution to moving future container volumes through new locations and over transportation corridors such as Prince Rupert to Chicago and Memphis, and Lazaro Cardenas to Kansas City were entirely omitted.

Challenges in developing accurate container forecasts were recently enumerated by the Citigroup transportation research unit in Hong Kong, examining carrier and shipper contract negotiations (20). The study highlights the great difficulties in determining good forecasts, as shown in Box 2. The study termed the shipping industry to be "a graveyard

Box 2. Black Magic—Container Statistics Do Not Add Up

"Efficiency gains have been tremendous. Container vessel turns can be underestimated, and so can the capacity added to a service as a result of additional port calls. We do not know how busy non-long haul lanes are and we do not know their utilization levels. That is why container shipping forecasting is like black magic"

Source: Charles de Trenck (20)

of forecasts, with an upside and downside that are continuously underestimated by analysts, consultants and companies alike." Academics need also to be added to that illustrious group as they access the same inadequate data and qualitative information from the industry. The central issue raised by the study centers is the lack of a centralized global database that can be accessed by carriers and shippers alike. The study used data from the key global providers of shipping data—Drewry, Clarkson, Dynamar, and PIERS—but then failed to give good discrimination because the aggregated data lacked "a way of stripping out the double counting, transshipments, and empties." In addition, though data are good for the Asia-Europe and trans-Pacific regions, data for "north-south, intra-Asia, tramps and regional trades are not being properly analyzed." The study concludes that a lack of understanding on container moves along the non-long haul routes, where growth may be high (or low) is also contributing to weak and inaccurate forecasts.

The 0-5538 contract required researchers to undertake a forecast of Texas landed container growth, notwithstanding the challenges identified in the Citigroup study. This Texas container forecast, which is detailed the Technical Report 0-5538-1 appendix, is now summarized to broadly define the magnitude of the potential demand driving the Texas container-oriented initiatives described later in this document. The objective of the exercise was to forecast the number of container TEUs (both import and export) that the port of Houston (or another Texas port) might handle at a future point of time. This is crucial for many reasons, allowing the port to determine capacity expansion requirements and investigate changes in port operation policies to better handle future container volumes.

The number of containers that a port will handle (as opposed to attract) depends mainly on the characteristics of the port's hinterland, the infrastructure and technology of various port facilities, the operational policies of the port (all supply side factors) as well as the global trade and economic trends (demand side factors). In addition, other important factors identified on the Citigroup work include vessel capacities, route (string) characteristics, and vessel speed. The resources of the 0-5538 team were not capable of capturing all these factors and the study forecast was developed based on historic port time series data.

Annual time series TEU data handled by the Port of Houston were available over a period of about 35 years (1970-2004). A regression model with just 35 data points may not produce efficient estimates of the parameters, so this study pooled similar time series data from several other U.S. ports to create a sizeable panel dataset for efficient parameter estimation. However, as panel data from several ports may not be able to capture heterogeneity (affects specific to individual ports), sophisticated panel data models that can incorporate heterogeneity were used in this approach. The annual container counts from 1984 to 2005 (22 observations each) of nine different US ports (Miami, Honolulu, Houston, Savannah, Charleston, Tacoma, Seattle, Oakland, and Hampton Roads) were collected and used as the dependent variable in the study. The annual population estimates of the corresponding counties of all the ports, the annual Gross State Product (GSP) of the corresponding states of the ports, the U.S. population estimates, and the Import Price Index (IPI) of all products are used as the independent variables. The pooled panel data hence consisted of 198 total observations, corresponding to 22 observations from each of the nine ports.

Six different panel data models were considered in this study based on the different ways through which heterogeneity (individual effects of the ports) can be introduced (see 0-5538-1F Appendix 1 for details). The simplest of these is the pooled ordinary least square (POLS) regression estimation, which estimates OLS regression estimation on the pooled data. While the least square dummy variable (LSDV) model introduces heterogeneity by estimating different constants for different ports, the random effects (RE) model captures heterogeneity by introducing one constant (considering average effect over pooled data) and considers the differences across the ports in the error terms.

In the random effects with autocorrelation (RE-Ar) model, autocorrelation is introduced in the RE model in the usual AR (1) process. By adopting a somewhat different modeling context, two different covariance structure models are considered. Here, heterogeneity takes the form of different variances rather than shifts in the means. Hence, the correlation across different ports becomes a part of the specification. Data are pooled similar to an OLS model and the errors are assumed to be correlated across panels. Further, based on the autocorrelation and heteroskedasticity, two variations of this model are considered in this study (heteroskedastic with correlation across panels and auto correlated (cov1 model), and heteroskedastic without correlation across panels and auto correlated (cov2 model)).

The Cov2 model, from the six models considered in this study, had the least sum of squares of errors, and was therefore used to determine future predictions of container counts at the Port of Houston. The results are graphed in Figure 6.1. The average growth rate of the independent variables between consecutive years from 1984 to 2005 is used to augment the independent variables over the period from 2005 to 2025. The dependent variable over the period 2005-2025 is calculated with the Cov2 model regression equation. The cov2 model predicts counts of just above 3,000,000 for the year 2020. However, the estimates provided by the cov2 model can be used as a lower bound for the future, as the recent trend (2001-2005) from the port of Houston suggests a sharp rise on container volumes. This is hardly surprising given the impact of the new Bayport terminal (still only in phase 1 form) and the size of the ships calling Houston, particularly those from Asia using the Panama Canal.

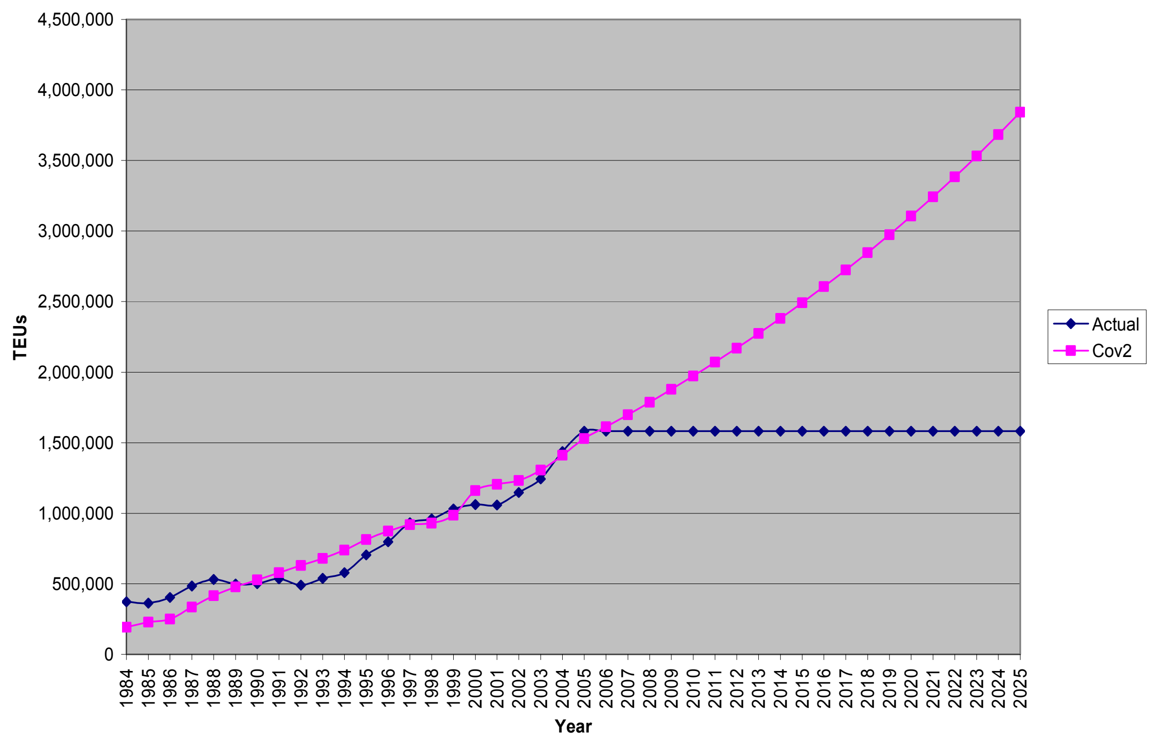

Figure 6.1: Houston Container Count Predictions Using the Cov2 Model (1984-2025)

This work complements a larger effort detailed in TxDOT Report 0-5068-2 (13), which examined the origins of the recent container trade growth in greater detail. It examined Houston's trading partners, the emergence of Chinese trade at Houston's terminals, the causes of growth in container volumes at the port, and finally, predicted TEU growth to 2020 using a simpler regression form to that reported earlier. In this earlier work, a critical variable used to predict future volumes was the population growth in Harris County and in Texas as a whole. This leads to a higher forecast than the one reported earlier—by around 25 percent—4,536,482 TEU by 2020. This latter figure also captures the impact of the new Bayport facility when built out—something not reflected in the time series data used in the cov2 model specified earlier. At this time, it is best to regard these two forecasts as likely lower and upper boundaries to the Port of Houston terminal throughput to 2020 given current operating practices (especially hours of operation) and no third Port of Houston terminal. The volume of containers processed by Texas deep water port terminals could change substantially over the period to 2020 if new terminals are opened at other Texas locations. The next section provides a mid-2007 update to report potential sites where additional state capacity could be provided.

Chapter 7. Concluding Remarks

The original focus of this study was to undertake an economic impact input-output (I/O) exercise that would capture the activity at all Texas ports. This effort would update an earlier study and allow TxDOT to understand the current level of economic activity at Texas' seaports. This understanding would play a role in state transportation planning. The study was awarded to a joint CTR-TTI team but work did not begin until the scope was clarified by TxDOT, following concerns expressed by some members of the Texas Ports Association (TPA). Almost all the larger Texas ports had undertaken economic impact studies and were understandably concerned about a new study providing different answers. Some of these concerns were justified as the results of economic impact studies are impacted by the timing, scale, and specifications of each study. Accordingly, it was agreed that where a Texas port had recently completed a study, the results would be reported to TxDOT in this project.

This reduced the scale of the original proposal and, although the study was delayed until the TPA issues were addressed, the work was expanded to provide both a forecast of container growth at Texas terminals and an estimate of the impact of Texas ports on the U.S economy. These are now presented with final comments on their use in transportation planning, together with recommendations on future work.

7.1 Texas Port Economic Impact Data for 2006

Table 7.1 contains data on the main impacts—jobs, personal income, economic value, and taxes—taken from studies conducted by Martin and Associates on the major Texas ports, and the researchers on the remainder, which were mostly the smaller ports who lacked the required resources to sponsor their own I/O studies.

Table 7.1: Texas Ports Summary: Aggregate Economic Impacts

	Jobs	Personal Income[1]	Economic Value[1]	Taxes[1]
Beaumont/ Port Arthur[2]	3,730	129	122	35
Brownsville[2]	38,429	1,926	2,780	174
Corpus Christi[2]	40,883	2,172	2,763	207
Freeport[2]	25,795	1,818	1,559	170
Houston[2]	785,049	39,265	117,590	3,691
Port Lavaca/ Comfort[2]	16,583	988	2,292	267
Texas City[2]	15,050	920	4,169	248
Victoria[2]	9,235	587	1,453	159
Galveston[3]	13,367	727	2,246	190
Harlingen[3]	88	4	19	1
Port Isabel[3]	948	23	86	6
Mansfield[3]	167	6	11	1
Palacios[3]	658	11	41	2
All Ports	949,982	48,576	135,131	5,151

Notes:
1 10^6 U.S. Dollars
2 Martin and Associates
3 Research Team

It is estimated that Texas ports as a group impact approximately 950,000 jobs, over $48 billion in personal income, and create $135 billion of economic value and over $5 billion of various taxes. It is noted that, with the exception of Galveston, which had not conducted an economic impact study at the time of the research, the CTR/TTI team were responsible for the smaller Texas ports. Smaller ports were an objective of the study and their data are interesting for both TxDOT state and district planning. The larger port economic impact studies were undertaken by Martin and Associates and this had the advantage of reducing differences due to method—there is no inter-consultant error bias, for example. Nevertheless, the scope of each Martin and Associates study may differ between ports and this may affect the results. The researchers were not asked to comment in detail on the Martin and Associates work, but Table 7.1 does show the significance of Houston in the state port impacts. Overall, Houston—comprising both public and private terminals—represents 83 percent of the jobs, 81 percent of the personal income, 87 percent of the economic value, and 72 percent of the taxes. Examining further, it is seen that the estimates for the "related" categories dominated their respective sub-total values. The percentage of the related category to total value was 75 percent for jobs, 66 percent for personal income, and 88 per cent for economic value. Martin and Associates define their use of the term and state that care was taken to avoid double counting while estimating the impacts of both exports and imports through Houston private and public terminals.

7.2 Texas Container Forecasting

The Cov2 model, fully described in Appendix G, Section 4.6, of the six models considered, had the least sum of squares of errors and was therefore used to determine the forecasts of container counts at the Port of Houston, as shown in Figure 6.1. The average growth rate in the independent variables between consecutive years from 1984 to 2005 was used to augment the independent variables over the period from 2005 to 2025. Although merging data in this way is not without risk, the "dark art" of container forecasting itself contains many challenges, so it was considered acceptable for this study, as long as the method was made transparent. The dependent variable over the period 2005-2025 is calculated with the Cov2 model regression equation. The cov2 model predicts counts of just above 3,000,000 for the year 2020 and these can be regarded as a lower bound for the overall forecast, as recent trends (2001-2005) in Port of Houston activities have shown a sharp rise in container volumes. This is not surprising given the impact of the new Bayport terminal (still only in Phase 1 form) and the increase in larger ships calling Houston, particularly those from Asia using the Panama Canal.

This work complements a larger effort detailed in TxDOT Report 0-5068-2 (13), which examined the origins of the recent container trade growth in greater detail. In this earlier work, a critical variable used to predict future volumes was the population growth both in Harris County and in Texas as a whole. This leads to a higher forecast than the one reported earlier—by around 25 percent—4,536,482 TEU by 2020. This latter figure also captures the impact of the new Bayport facility when built out—something not reflected in the time series data used in the Cov2 model specified earlier. At this time, it is best to regard these two forecasts as likely lower and upper boundaries to the Port of Houston terminal forecast out to 2020 given current operating practices (especially hours of operation) and no third Port of Houston terminal. The volume of containers processed by Texas deep water port terminals could change substantially over the period to 2020 if new terminals are opened at other Texas locations.

7.3 Impacts of Dredging Texas Shallow Draft Waterways on the U.S Economy

As detailed in Chapter 4 of this report, the researchers decided to estimate national impacts through the use of a static general equilibrium model developed for the International Trade Commission—USAGE-ITC. This model, which in its present form has not been used before for this purpose, was supported by ITC staff on this study. For the shallow draft impacts, input data were prepared by the researchers then sent to Washington where ITC staff ran the actual model. Deep draft analyses were run in-house, consulting with ITC staff where necessary.

The model was configured to evaluate the impacts associated with Texas' shallow draft and deep draft waterways. The shallow draft work evaluated the impact to the U.S economy of reducing dredging from the nominal 12 foot to an approximate 10 foot draft—not closing the waterway down, as was the case in previous GIWW studies. A 10 foot draft limits barges to 8 feet of draft in order to allow a safety factor and reduce the likelihood of grounding the tow. The USAGE-ITC model derives estimates of Gross Domestic Product (GDP) and the associated variables of real consumption, investment, export, and imports.

Table 7.2: Texas Shallow Draft Waterways: Impact of a Five Foot Reduction

Waterway	Impact on U.S. Gross Domestic Product
GIWW	190.1
Victoria	11.3
Chocolate Bayou	14.7
Arroyo	1.3
Total	217.4
Notes: 10^6 U.S. Dollars 2006	

Researchers estimated the change in transportation cost when barge drafts are limited to 8 feet (a reduction of less than 1 foot from current drafts), as detailed in Chapter 3, and these data were used in the USAGE-ITC modeling. The GDP results are given in Table 7.2 and provide interesting information on both the Texas portion of the GIWW and associated shallow draft waterways. The data allow those familiar with dredging programs to estimate a quick cost-benefit ratio—for example, if the GIWW dredging is $20 million annually, then the benefit-cost ratio is around 10 to1. It should be noted that for cost benefit analysis, the impact on GDP is not strictly a net benefit. However, as a back of the envelope approximation, this is appropriate. The work also illuminates the value to the nation of keeping the GIWW open and fully dredged, in addition to the jobs, investment, and taxes also generated by the waterway activities.

7.4 Deep Draft Texas Channels

The vessel cost data used in this application of the USAGE-ITC model—the deep draft channels—were based on an analysis of that portion of the vessel calls impacted by allowing the channel depth to decrease by 5 feet. For example, if a channel has an actual depth of 40 feet and it deteriorates to 35 feet deep, a fraction of ships using the channel will carry fewer tons of cargo to reduce their draft. The cost of operating the vessel is broadly fixed, so moving less cargo increases the average cost for moving each ton of cargo. This raises the cost of serving the port because it prevents the operation of vessels with better economies of scale and lower average operating costs. Furthermore, if industry is to maintain the same level of activity, additional shipments will be required. Over the long term, industries may adjust to deterioration in channel depth. The cargo may also be shifted to other ports, or shippers may use different vessels, or even modes. To keep the problem tractable, we have assumed that these factors will not play a role in the short term.

The impact of a 5 foot reduction of deep water channels on the 2006 U.S GDP is given in Table 7.3. The aggregate Texas port impact is over $1 billion annually, although again it is noted that the three deepwater channels estimated by Martin and Associates dominate the total impact. This strongly suggests a methodological difference in the estimation technique undertaken by the two teams. The calculations of the CTR/TTI team is described in Chapter 3 and Appendices A, B and C. It is recommended that the analysis be repeated at some future period with channel impacts measured in a consistent manner to test for any distortions caused by different methods.

Table 7.3: Texas Port Impacts on US GDP Following a Draft Reduction of 5 Feet

Port	U.S. Gross Domestic Product 2006[1]
Brownsville	2.5
Corpus Christi	6.9
Freeport	7.8
Galveston	2.8
Houston[2]	792.6
Port Lavaca-Matagorda	3.2
Sabine-Neches[2]	247.4
Texas City	27.8
Total	1,091
Notes: [1] 10^6 U.S. Dollars [2] Martin and Associates	

On the subject of general equilibrium modeling, it does appear that this approach offers relevant complementary data to traditional I/O approaches. It offers particular insight on the national impacts of engineering, policy, and programming changes impacting U.S ports. USAGE-ITC holds promise in producing improved estimates of the impacts of large single projects (like Mississippi locks) or U.S trade policy changes, such as ethanol tariffs. Finally, USAGE-ITC in is also suited to evaluating non-maritime transportation policy problems and can be applied to other modes, including truck, rail, air, and pipeline transportation.

The focus of port economic impact studies, especially those measuring maritime impacts, has generally on estimating the local and regional employment, tax, and wage benefits of a transportation project. The metrics are presented as measures of a community's welfare and are often used to justify local support for investment in new infrastructure, such as a bond issuance for a new terminal. They are also used to allocate funds to maintain existing infrastructure, or simply as a means to illustrate ties to the local community for the purposes of setting public policy and generating political support favorable to port activities. What they lack is a more precise measure of national impacts at the national level.

The research study findings suggest that a general equilibrium model can be used to evaluate the national impacts of maritime investments. The study outlines the process and provides results computed from a study of selected Texas shallow draft waterways and deep draft waterways. These results reveal positive, measurable economic impacts within an unusually robust framework and suggest that this method can provide effective analyses of many policy issues relating to U.S. waterways. The results strongly suggest that general equilibrium models in general, and the USAGE-ITC in particular, can be effectively applied to marine transportation policy questions. Moreover, the results developed with this approach can complement the substantial body of knowledge derived from the input-output methods now typically used to measure port impacts in the United States.

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Appendix A: Statistics Derived from Colorado Lock Data and Waterborne Commerce Statistics

The main assumption was that the GIWW would be allowed to shoal to the point where barge drafts must be limited to 8 feet. Table A1 provides a 4-month composite of the values.

Table A1. Barge and Fleet Characteristics (4-Month Composite)

	Tanker	**Dry**
Wtd Avg Draft	8.86	8.70
Wtd Avg Tons/barge	2612	1887
Wtd Avg Tons/ft of draft	372.54	278.21

NOTE: All barge and fleet characteristics presented are based on Colorado Lock data for January, April, September, and December 2005.

The Colorado Lock data indicate a ratio of 2.4 barges per tow for dry cargo movement and 1.6 barges per tow for liquid cargo movements; see Table A2.

Table A2. Barges Per Tow (Loaded)

Barges Per Tow (Loaded)				
	Dry		Liquid	
Month	Number of tows	Avg. barges per tow	Number of tows	Avg. barges per tow
January	85	2.52	291	1.64
April	97	2.27	274	1.56
September	51	2.51	231	1.68
December	79	2.46	315	1.58
Wtd. Avg. Barges/tow		**2.43**		**1.61**

NOTE: Data are for barges drafting greater than 8 feet.

Appendix B: Calculations for Texas Reach of GIWW

Assumptions

The main assumption was that the GIWW will be allowed to silt in to the point that barge drafts must be limited to 8 feet. Towboats were assumed to draft one foot more than barges.

All barge and fleet characteristics were based on data sampled from the Colorado Locks data[45] for 2005.

Cost information for operating towboats and barges were taken from USACE's Economic Guidance Memorandum 05-06, which provides Shallow Draft Vessel Operating Costs for 2003. An adjustment was made to fuel cost because of dramatic increases in fuel costs since 2003.[46] The other operating costs, reported by USACE, were inflated using the Inland Waterways Towing Transportation Producer Price Index. This resulted in a 12.7 percent increase in the costs as provided in the memorandum.

The 1800-2000 HP category towboat was used for this analysis. A speed of 5 mph was assumed.

For tank barges, the costs of the 297.5 ft x 54 ft barge without coils were used. For dry cargo barges, the costs of the 195 ft x 35 ft covered hopper were used.

Base Data

From the USACE data, the average trip length for the Texas reach of the GIWW was calculated to be is 431 miles (i.e., total trip ton-miles divided by total tons). The average trip duration was calculated by dividing 431 miles by 5 mph, which equals 86 hours or 3.6 days.

Towboat cost per trip:
($5,418.59/day + $1,613.10 fuel adjustment) x 3.6 days = $25,314

Tanker barge cost per trip:
$673.20/day x 3.6 days = $2,424

Dry barge cost per trip:
$121.69/day x 3.6 days = $438

Tanker trip cost: $25,314 + ($2,424 per barge x 1.6 barges per tow) = $29,192
Dry cargo trip cost: $25,314 + ($438 per barge x 2.4 barges per tow) = $26,365

Liquid Cargo Analysis

From the USACE data, the number of tanker barges drafting more than 8 ft in 2004 was 19,478.

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[45] The data indicated an average of 2.4 barges per tow for dry movements, and 1.6 barges per tow for liquid movements.

[46] Cost figures were updated to reflect the dramatic increases in fuel costs that have occurred since the latest USACE figures were published in November 2004. The fuel cost per gallon for this analysis is: $2.015 ($1.815 average for 2005 + $0.20 Waterway Tax.), which is 173% of the cost in the USACE schedules. The Deficit Reduction Tax of $0.043 is set to expire on January 1, 2007, and was therefore excluded.

This equals 12,174 trips (19,478 barges ÷ 1.6 barges per tow).
The cost of these trips = 12,174 x $29,192 = $355,383,408.
Actual tons transported on tanker barges:
19,478 barges x 2,612[47] tons (avg/barge) = 50,876,536 tons

Cost/ton under "maintained channel" scenario = $6.985

With Reduced Draft
Current weighted average draft is 8.86 ft.
Required cargo reduction per barge: 0.86 x 372.54= 320 tons[48]

Adjusted tons transported (reduced tonnage necessitated by required maximum draft of 8 feet assuming the same number of trips): 19,478 x (2,612 – 320) = 44,643,576 tons

Adjusted cost/ton = $7.960

Increase in transportation cost due to required maximum draft of 8 feet:
($7.960 – $6.985) x 44,643,576 = $43,527,487

However, this leaves 6,232,960 tons "stranded." To move this cargo will require additional trips.
The additional trips required with a maximum draft of 8 ft =
(50,876,536 – 44,643,576) ÷ (1.6 x (2612-320)) = 1,700 trips
Cost of additional trips is 1,700 x $29,192 = $49,626,400

Total increase in transportation costs for tanker traffic: **$93,153,887**

Dry Cargo Analysis

From the USACE data, the number of barges drafting more than 8 ft in 2004 was 4,022.
This equals 1,676 trips (4,022 ÷ 2.4).
The cost of these trips = 1,676 x $26,365 = $44,187,740.
Actual tons transported on dry barges:
4,022 barges x 1,887 (avg/barge)[47] = 7,589,514

Cost/ton under "maintained channel" scenario = $5.822

With Reduced Draft

Current weighted average draft is 8.70 ft.
Required cargo reduction per barge: 0.70 x 278.21 = 195 tons

Adjusted tons transported (reduced tonnage necessitated by required maximum draft of 8 feet, assuming the same number of trips) 4,022 x (1,887 – 195) = 6,805,224 tons

[47] From Colorado Lock Data
[48] Tons per foot derived from Colorado Lock Data

Adjusted cost/ton = \$6.493

Increase in transportation cost due to required maximum draft of 8 feet:
(\$6.493 – \$5.822) x 6,805,224 = <u>\$4,566,305</u>

However, 784,290 tons were removed to ensure barge drafts are limited to 8 feet. To move this cargo requires additional trips. The additional trips given the reduced draft =
(7,589,514 – 6,805,224) ÷ (2.4 x 1,692) = 194
Cost of additional trips is 194 x \$26,365 = <u>\$5,114,810</u>

Total Increase in transportation costs for Dry Cargo Traffic: <u>**\$9,681,115**</u>

Total increase in transportation cost for Texas Segment of GIWW: \$102,835,002

Potential Cost Savings

Table B1 provides the cost figures for the Corps of Engineers.

Table B1. Annual operating and maintenance cost incurred by Corps of Engineers

FY	Original Cost	Price Adjusted Cost	Cubic Yards
1998	4,373,188	5,560,805	2,085,533
1999	15,393,672	19,356,286	10,040,005
2000	17,242,438	20,905,531	10,521,685
2001	22,771,467	27,648,737	7,885,262
2002	20,012,873	24,706,351	9,564,817
2003	14,403,850	17,514,007	8,455,221
2004	12,348,604	13,573,855	6,104,967
2005	10,405,599	10,405,599	4,327,086
Average	**14,618,961**	**17,458,896**	

Appendix C: Analysis of Effect of Shoaling for Colorado River

Assumptions Base Data and Costs:

The main assumption regarding shoaling is that the GIWW will be allowed to shoal to less than 8 feet. Towboats are assumed to draft one foot more than barges. All barge and fleet characteristics are based on a sample of Colorado Locks data for 2005. These data indicate an average of 2.4 barges per tow for dry barges, and 1.6 barges per tow for liquid barges.

1. Cost figures for operating towboats and barges were taken from USACE's Economic Guidance Memorandum 05-06, which provides Shallow Draft Vessels Operating Costs for 2003. An adjustment was made to fuel cost for this analysis based on historical prices due to the dramatic increases in fuel costs since 2003[49]. The other operating costs reported by USACE were inflated using the Inland Waterways Towing Transportation Producer Price Index. This caused a 12.7% increase to the costs provided in the memorandum.

2. The towboat HP used for this analysis is the 1800-2000 HP category.
   A speed of 5 mph was assumed.

3. For liquid barges, the 297.5 ft x 54 ft barge without coils was used.
   For dry cargo barges, the 195 x 35 covered hopper barge was used.

4. Using USACE data, the average trip length for this reach is 247 (total trip ton-miles divided by total tons). The average trip duration is 247 miles ÷ 5 mph = 49 hours or 2.0 days.

Costs:

Towboat cost per trip:
($5,418.59/day—USACE + $1,613.10 fuel adjustment) x 2.0 = $14,063

Tanker barge cost per trip:
$673.20 * 2.0 = $1,346

Dry barge cost per trip:
$121.69 * 2.0 = $243

[49] Cost figures were updated to reflect the dramatic increases in fuel costs that have occurred since the latest USACE figures were published in November 2004. The fuel cost per gallon for this analysis is: $2.015 ($1.815 average for 2005 + $0.20 Waterway Tax.), which is 173% of the cost in the USACE schedules. The Deficit Reduction Tax of $0.043 is set to expire on January 1, 2007, and was therefore excluded.

Tanker trip cost: $14,063 + ($1,346 x 1.6) = $16,217
Dry cargo trip cost: $14,063 + ($243 x 2.4) = $14,646

Liquid Cargo Analysis:

Per USACE, the number of tanker barges drafting > 8 ft in 2004 was 115
This equals 72 trips (115 ÷ 1.6).
The cost of these trips = 72 x $16,217 or $1,167,624.
Tons actually transported on these barges:
72 barges x 2,612 (avg/barge)[50] = 188,064

Cost/ton under "as is" scenario = $6.209

With Reduced Draft:

Current weighted average draft is 8.86 ft.
Required cargo reduction per barge: 0.86 x 372.54[51] = 320 tons

Adjusted tons transported (amount that could be moved in the same number of trips with maximum draft of 8 ft): 72 x (2,612 – 320) = 165,024
(2,292)
Adjusted cost/ton = $7.075.

Increase in cost based on current number of trips with maximum draft of 8 ft:
($7.075 – $6.209) x 165,024 = $142,911

However, this leaves 23,040 tons "stranded". To move this cargo will require additional trips.
The additional trips required with a maximum draft of 8 ft =
(188,064 – 165,024) ÷ (1.6 x 2292) = 7
Cost of additional trips is 7 x $16,217 = $113,519

Total Increase for Tanker Traffic: $256,430

Dry Cargo Analysis:

No Dry Cargo was reported, so this category made no contribution at this time.

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[50] From Colorado Lock Data
[51] Tons per foot derived from Colorado Lock Data

Potential Cost Savings:

Annual O&M cost incurred by Corps of Engineers:

FY	Original Cost	Price Adjusted Cost	Cubic Yards
1998	$537,139	$683,009	N/A
1999	0	0	N/A
2000	0	0	N/A
2001	0	0	0
2002	$469,936[52]	$580,147	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
Average	**$125,884**	**$157,894**	

Differential Between Costs Avoided by Dredging and Cost of Dredging:

(Annual basis)

Costs Avoided	Cost of Dredging	Difference
$256,430	$157,894	$98,536

Ratio of savings due to dredging vs. savings due to not dredging: 1.6. This is effectively a benefit-cost ration that, since it exceeds 1 indicates that the investment is worthwhile if the budgets are unconstrained.

[52] Also included in GIWW figures for Galveston to Corpus reach.

Appendix D: Calculations for the Port of Brownsville

The data supplied for vessel transits into and out of the Port of Brownsville in 2005 included the following statistics. Tables D1 and D2 provide the data for inbound and outbound transits.

Inbound Transits

Table D1. Inbound Data

Number of voyages where sailing draft exceeded the computed reduced channel depth	43
Tonnage handled at this port on these voyages	1,016,772 mt
Required tonnage reduction on all inbound voyages ("excess tonnage")	128,307 mt

<u>Inbound Cost Calculations</u>

Total cost-per-ton differential:

Sum of (adjusted/reduced tons handled at this port[53] x cost per ton differential per voyage[54])= $476,378

Cost of "excess" tonnage

Average total tons per voyage with new draft restriction

Bulk Carriers: 1,002,928/26 = 38,574 tons/voyage
Tankers: 514,593/16 = 32,162 tons/voyage
General Cargo: 36,367/1 = 36,367 tons/voyage

Number of additional voyages required;

"Excess" tonnage / average tons per voyage
Bulk Carriers: 82,743/38,574 = 2.1 voyages
Tankers: 41,493/32,162 = 1.3 voyages
General Cargo: 4,071/36,367 = 0.1 voyages

Weighted average cost per voyage:

Sum of (Adjusted tonnage per voyage x cost per voyage)/total adjusted tonnage

[53] Tons handled at this port minus the required tonnage reduction due to reduced channel depth
[54] Calculated on a voyage by voyage basis

Bulk Carriers:
365,328,475,080/1,002,928 = $364,262/voyage
Tankers:
126,806,098,747/514,593 = $246,420/voyage
General Cargo
23,672,293,606/36,367 = $650,928/voyage

Cost of additional voyages
No. of voyages x weighted average cost per voyage:
Bulk Carriers: 2 x 364,262 = $728,524
Tankers: 1 x 246,420 = $246,420
General Cargo: none
Total: $974,944

<u>Total increase in transportation cost for inbound traffic =</u>
$974,944+ $476,378= $1,451,322

Outbound Transits

Table D2. Outbound Data

Number of voyages where sailing draft exceeded the reduced channel depth	6
Tonnage handled at port in terms of these voyages	75,029 metric tons
Required tonnage reduction on all outbound voyages ("excess tonnage")	21,338 metric tons

<u>Outbound Cost Calculations</u>

Total cost-per-ton differential

Sum of (adjusted/reduced tons handled at this port[55] x cost per ton differential per voyage)

$51,518

Cost of "excess" tonnage

Average total metric tons per voyage with new draft restriction:
Bulk Carriers: 35,548/1 = 35,548 metric tons
Tankers: 135,207/4 = 33,802 metric tons

[55] Tons handled at this port minus the required tonnage reduction due to reduced channel depth

General Cargo: 29,416/1 = 29,416 metric tons

Number of additional voyages required:
"Excess" tonnage / average tons per voyage
Bulk Carriers: 5,003/35,548 = 0.1 voyages
Tankers: 10,207/33,802 = 0.3 voyages
General Cargo: 6,128/29,416 = 0.2 voyages

Weighted average cost per voyage
Sum of (Adjusted tonnage per voyage x cost per voyage)/total adjusted. tonnage
Bulk Carriers:
20,752,038,627/35,548 = $583,775
Tankers:
6,464,583,861/135,207 = $47,812
General Cargo
24,648,626,576/29,416 = $837,933

Cost of additional voyages
No. of voyages x weighted average cost per voyage:
Bulk Carriers: none
Tankers: none
General Cargo: none
Total: $0

Total increase in transportation cost for outbound traffic =
$0 + $51,518 = $51,518

TOTAL ANNUAL TRANSPORTATION COST INCREASE DUE TO DECREASED CHANNEL DEPTH

Inbound	$1,451,322
Outbound	$51,518
TOTAL	$1,502,840

Potential Cost Savings

Table D3 provides the cost figures for the Corps of Engineers.

Table D3. Annual operating and maintenance cost incurred by Corps of Engineers

FY	Original Cost	Price Adjusted Cost	Cubic Yards
1998	1,739,623	2,318,917	1,593,894
1999	2,990,594	4,031,321	691,337
2000	50,000	69,900	-0-
2001	4,229,643	5,904,582	2,569,518
2002	2,000,000	2,746,000	633,146
2003	2,796,432	3,898,226	858,848
2004	1,264,181	1,949,367	355,957
2005	1,377,432	2,334,747	277,997
Average	**2,055,988**	**2,475,626**	

Appendix E: Local and Regional Impacts

1. Survey Methodology

The Port Director at each Texas port included in the analysis was contacted by e-mail and telephone and to request a list of companies that were dependent on the port for their business. Each Port Director provided the research team with a list of companies and relevant contact information.

Each of the port-dependent companies was contacted by phone. During the telephone conversation, the researcher explained the purpose of the study, and requested a fax number or e-mail from the respondent that could be used to send a copy of the questionnaire.

A questionnaire[56] was prepared and sent to each of the identified port-dependent companies to determine the percentage of their business that is dependent on the port, the number of company employees, the company expenditures for 2006, and company taxes paid in 2006. Company employment was the only input required by IMPLAN, but the expenditure data allowed for a comparison of the revenues generated by IMPLAN with the actual expenditure data provided by the businesses. If the IMPLAN-generated revenues based on business employment were significantly higher or lower than the reported business expenditures, the company was generally re-classified into a sector that more closely resembles the business.

A second survey (asking only for the number of employees) was sent to those companies that did not respond to the questionnaire. It was felt that the businesses would be more likely to provide employment information as compared to expenditure data. Although the lack of expenditure data prevented the verification of the IMPLAN-generated revenues, the shorter survey did increase the business response rates. However, some companies were included in the Texas Workforce Commission database, which listed the number of employees and revenues for those companies in the database. This resource allowed the research team to compare the provided employment numbers with the ranges listed. In all cases, the employment data provided was within the range included in the database.

Finally, the respective port directors were asked to provide employment information for those businesses that did not respond to the employment question after more than five attempts to contact them. The Port Directors were able to estimate the number of employees at each of the companies that did not respond.

2. Responses

Table E1 summarizes who provided the required input data to IMPLAN by port. For each port, the first table row provides the number of company responses by the manner in which the employment information was obtained and the second row expresses this information as a percentage.

[56] The questionnaire had a similar format for all Texas port-dependent businesses evaluated with the exception of businesses dependent on Port Mansfield. The survey approach and questionnaire used for Port Mansfield-dependent businesses are discussed separately.

Table E1: Responses by Port

Name of Port	Businesses: Completed Full Survey	Businesses: Provided Employment Information	Port Director Provided Employment Information
Port of Galveston*	3	23	13
	7.7%	59.0%	33.3%
Port of Harlingen	0	4	1
	0.0%	80.0%	20.0%
Port of Port Isabel	0	3	3
	0%	50%	50%
Port of Palacios	4	7	1
	33.3%	58.3%	8.3%

* Note: Employment information could not be obtained for three of the companies dependent on the Port of Galveston, so they were excluded from the analysis.

As is evident from the table, in most cases the required data was collected from the port-dependent companies themselves. Only in a few cases were the data obtained from the Port Director.

3. IMPLAN Methodology

Port of Galveston

The study area specified in IMPLAN for modeling the impacts of the Port of Galveston included Galveston County, Brazoria County, Chambers County, and Harris County. This area was thought to be sufficiently large to capture any leakages into surrounding areas: Brazoria, Chambers, and Harris County. Once the data was entered into the IMPLAN model, two issues became apparent.

- The first issue related to the representation of the cruise industry, as two estimates for the direct impacts were available.
- The second issue related to a lack of data for three companies dependent on the port that did not respond in time.

The direct impacts of the cruise industry was obtained from a study prepared for the International Council of Cruise Lines entitled *The Contribution of the North American Cruise Industry to the U.S. Economy in 2004.* This study presented the impacts of the cruise industry in two different ways—each of which could be used to estimate the impacts of the Galveston cruise industry. First, it provided a breakdown of the direct impacts of the U.S. cruise industry by sector. Secondly, it provided the total direct impacts of the Texas cruise industry. The decision was made to enter the Texas cruise industry data into IMPLAN. Although the former data was more disaggregated, many of the U.S. cruise industry impacts listed were probably not applicable to Galveston, such as air transportation. The Texas cruise industry impacts were scaled down to represent the percentage that Galveston contributes. These impacts were classified under the "water transportation" sector, which was believed to represent the cruise industry. The IMPLAN model was also run with the data for the U.S. cruise industry categorized by sector. The results shown from both model runs were very similar. The cruise industry dominates the economic impacts of the Port of Galveston to the extent that it is believed that the companies that were excluded would most likely not have altered the results significantly. Despite these issues, IMPLAN does appear to provide an accurate approximation of the economic impacts of the Port of Galveston.

Port of Harlingen

The study area for modeling the economic impacts of the Port of Harlingen included Cameron County, Hidalgo County, and Willacy County. This area was assumed to be large enough to capture any leakages into surrounding counties. The employment values obtained were entered into IMPLAN, and the associated revenues generated by the model seemed reasonable. The only issue encountered was in the sector classification of the three pesticide and fertilizer manufacturing companies at the Port of Harlingen. The specified study area did not have embedded multipliers for the "pesticide and other agricultural chemical manufacturing" sector, which appeared to be the correct sector for describing the operations of these companies. Instead, the "fertilizer, mixing only, manufacturing" sector was used to determine the impacts associated with these companies. This could introduce some inaccuracy in the results. However, both sectors seem to relate to the operations of these companies as the NAICS codes listed in IMPLAN corresponded to both the pesticide and the fertilizer sector.

Port of Port Isabel

The study area for modeling the economic impacts of Port Isabel included Cameron County, Hidalgo County, and Willacy County. This area was considered large enough to account for any leakages into the counties around Port Isabel. Two main issues were encountered in running the IMPLAN model for Port Isabel:

- The first issue was that one company's employees varied by season, and
- The second issue was that the annual number of shrimpers in Port Isabel (provided by the Port Director) could not be verified because there were no companies employing these shrimpers to contact.

The company that employed seasonal workers presented an issue because only a fraction of their employees worked year-round on business that was port-dependent. The remainder of the year, the majority of the employees worked on agriculture-related activities. In an attempt to correctly represent the number of port-dependent employees at this company, a weighted average number of port-dependent employees was calculated based on the monthly number of employees working on port-dependent businesses in the previous year.

The second issue—i.e., whether to use the employment numbers given by the Port Director for the shrimp industry in Port Isabel—was problematic, because the shrimp industry does have a significant economic impact. Although the employment number was merely an estimate, it was thus decided to enter the given estimate of 300 shrimpers in IMPLAN.

Port of Palacios

The study area for modeling the economic impacts of the Port of Palacios included Matagorda County, Brazoria County, Wharton County, and Jackson County. This area was considered large enough to account for any leakages into the counties around the Port of Palacios. Two issues arose in constructing and entering the direct impact data in the IMPLAN model for the Port of Palacios:

- The first issue related to the fact that it was not clear which of the shrimp companies caught the shrimp and which processed it, and which both caught and processed shrimp.
- The second issue involved selecting the sector that best described the operations of two of the three boat repair companies at the Port of Palacios.

The shrimping industry is the most important industry in Palacios. Many of the shrimping companies that were contacted were involved with either the catching or processing of shrimp. The main issue was how to distinguish the companies that catch the shrimp from those that process the shrimp. The Port Director was asked to assist in identifying which companies caught shrimp and which processed the shrimp. The majority of the companies were involved only in catching the shrimp. However, one company both caught and processed shrimp. For this company, it was necessary to know how many employees were involved in catching shrimp and how many employees were involved in processing shrimp. The company was called again and asked to provide the latter information. The assistance of the Port Director and the information received from the one shrimp catching and processing company allowed for the assignment of all the companies within the shrimp industry in the Port of Palacios to the correct IMPLAN sector.

The second issue involved the selection of the sector that best described the operations of two of the boat repair companies. Two IMPLAN sectors—"ship building and repairing" and "boat building"—were considered. The difference in the IMPLAN-generated revenue between classifying the companies as "boat building" compared to "ship building and repair" was, however, small. Either classification thus seemed appropriate. In the end, the decision was made to classify the boat repair companies as "boat building." However, it was decided versus "ship building and repairing" even though the latter sector included repairs. It was argued that ships tend to be much larger vessels compared to boats, and as such boat building seemed to be the appropriate classification for these companies.

4. Port Mansfield

Fishing Guides

A questionnaire consisting of 17 questions was developed to administer to the Port Mansfield fishing guides. The objectives of this questionnaire were to (a) gather information about the fishing guide industry in Port Mansfield, (b) identify other port-dependent businesses that would need to be contacted, and (c) obtain the revenues generated by each fishing guide in 2006. The first four questions related to the fishing industry in Port Mansfield and how those who visit the port spend their time. The answers to questions 5 through 8 allowed for the estimation of the revenues generated by each fishing guide in 2006. The last nine questions asked about other businesses in Port Mansfield that were related to the fishing industry (i.e., thus dependent on the port).

It became clear after contacting the first eight guides that a number of the questions could be eliminated, because all the guides were providing the same answers[57]. All questions distinguishing sport fishing from recreational fishing were also eliminated, because all of the guides contacted responded that there was no difference in Port Mansfield. The elimination of these questions left only eight questions, which mainly focused on the revenues of the fishing guides. The abbreviated version of the questionnaire was used in all further contact with the guides.

A contact list for 51 Port Mansfield fishing guides was developed from the contact information listed on the Port Mansfield Chamber of Commerce website, supplemented by additional fishing guide information listed on the Get-A-Way Adventures Lodge website. The names on the two lists were then compared to ensure that the contact information was correct.

The initial contact with the fishing guides was through e-mailing all the guides who had an e-mail address listed as part of their contact information. The e-mail briefly explained the project objectives; with the survey attached in a Word file. The guides who did not have an e-mail address listed were contacted by telephone to determine whether they had an e-mail address or fax number that could be used to send to them a copy of the survey. E-mailing or faxing the questions to the guides provided them with time to consult their previous year's records, which were needed to answer some of the questions. All the guides that received a copy of the questionnaire were given at least 5 business days to review the questions and find the answers before they were contacted again.

Some of the guides responded by e-mailing or faxing the answers to the survey questions. A substantial number of questions, however, were not answered by the majority of guides. Each of the guides was subsequently called and asked to answer the outstanding questions. If a guide could not be reached after at least five phone calls at different times, he/she was classified as a non-response. Some of the other non-responses were the result of telephone numbers that were out of service or belonged to individuals who no longer worked as fishing guides or who had moved to Port Isabel.

Table E2 summarizes the response statistics for the fishing guide surveys. It is evident that of the 51 guides contacted, 55 percent completed the survey.

Table E2: Survey Response Statistics

Number of Guides	Number of Respondents	Response Rate (%)	Number of Non-Responses	Non-Response Rate (%)
51	28	54.9%	23	45.1%

Table E3 summarizes the number and percentage of non-responses by the reason for non-response. From Table D3, it is evident that the two main reasons for a non-response were the fishing guide's refusal to participate in the study, and the researchers terminating the effort to obtain a response. The fishing guide who relocated to Port Isabel did so because the channel in Port Mansfield had silted up to the extent that his boat was damaged multiple times.

[57] These questions related to where the fishermen came from, where they shop and lodge when in Port Mansfield, and where they can rent fishing and camping equipment.

Table E3: Reasons for Non-Response

Move to Port Isabel	Phone Number not in Service	Refused to Talk	Effort Terminated (Called 5 times)	Other (e.g., Retired, Deceased)	Total Non-Response
1	3	7	8	4	21
4.4%	13.0%	30.4%	34.8%	17.4%	100%

Other Port-Dependent Businesses

The main objectives of surveying the other port-dependent businesses in Port Mansfield were to determine (a) their revenues for 2006 and (b) their number of full-time and part-time employees. The business revenue information for each company was preferred to the employment data, but in some cases only the number of employees was provided. The questions differed slightly by company depending on their business.

Many of the companies in Port Mansfield were undertaking a variety of activities (e.g., vacation home rental in addition to catering) and thus their operations resembled more than one sector. Respondents were thus asked to specify the revenues and number of employees for each different activity to ensure that the impacts were attributed to the right sector. It was also important to obtain the percentage of business revenue generated in 2006 from non-resident fishermen. Most companies responded that 90 to 100 percent of their business revenue was from non-resident fishermen.

A list of 34 port-dependent businesses was compiled from the Port Mansfield Chamber of Commerce website and the responses from the fishing guides. The Chamber of Commerce website listed contact information for most of the businesses. The President of the Port Mansfield Chamber of Commerce, Terry Neal, provided the contact information for those businesses not listed on the website. The compiled list was reviewed to identify individuals who were listed as the contact person for more than one company, to prevent having to call any one person multiple times.

As with the fishing guides, the companies that listed e-mail addresses were contacted first. Businesses that did not list e-mail addresses were contacted by telephone and asked to answer the questions without being able to review the questions first. Some respondents were able to provide the required information, but a fax or e-mail with a copy of the questionnaire was sent to those that needed more time to find the answers to some of the questions.

Companies that did not respond to the e-mails or faxes were contacted again. Those that could not be reached after five telephone calls at different times were not pursued. As a last resort, Terry Neal was asked to provide the number of full-time and part-time employees at each of these companies for which data had not yet been collected.

Thus, of the 34 companies for which contact information was obtained, over half (i.e., 20 companies) provided revenue and/or employment data to the research team. Terry Neal at the Chamber of Commerce provided employment data for 10 companies that did not respond after repeated attempts. No data could be collected for four companies. These were all real estate companies that had been sold to another real estate company in Port Mansfield.

Table E4 summarized the number and percentage of responses (by source) and non-responses.

Table E4: Survey Response Statistics

Respondents			
Businesses	**Chamber of Commerce (e.g., Employment Data)**	**Non-Response (Sold the Business)**	**Total**
20	10	4	34
58.8%	29.4%	11.8%	100%

5. IMPLAN Methodology

The study area for modeling the economic impacts of the Port Mansfield included Willacy County, Cameron County, and Hidalgo County. This area was considered large enough to account for leakages into the counties surrounding Port Mansfield. However, a major issue that arose was that the production functions and parameter embedded in the IMPLAN model (associated with the specified study area) were not representative of the fishing industry in Port Mansfield. The reason was that the production functions embedded in IMPLAN are generated from average national data, and were clearly not representative of the relationship between employment and revenues of the fishing industry in Port Mansfield.

For example, when the revenue data obtained from the fishing guides were entered into the IMPLAN model, the model reported more than twice as many fishing guides in Port Mansfield than were actually there. This resulted from the fact that the default data for the study area assumed an average revenue of just over $18,000 for every employee in the fishing sector. The average weighted[58] output or revenues generated by each Port Mansfield fishing guide, however, exceeded $58,000. Thus, the revenue values had to be revised to more accurately reflect the number of fishing guides and the generated revenues at Port Mansfield.

At the same time, the embedded proprietors' income[59] value for the fishing guides had to be adjusted to reflect the "take home" income of the fishing guides. Terry Neal was contacted once again and asked to estimate the average daily expenditures of a fishing guide. He reported that the average daily expenditures on ice, fuel, and bait were approximately $85. The expenditures were subtracted from the daily guide fee to calculate the "take home" income per fishing day. Given the number of fishing days per year, the average "take home" income per fishing guide was calculated at just over $48,000. The embedded data were changed to reflect the calculated revenues and proprietor income values. This improved the accuracy of the model estimating the economic impacts attributable to the fishing guide sector in Port Mansfield.

The second issue that arose related to the NAIC codes that categorize boat storage in IMPLAN. This resulted in boat storage being aggregated into the "Real Estate" sector. Similar to the situation with the fishing guide sector, this categorization resulted in an incorrect relationship between employment and generated revenues. However, the production functions could not be altered for that sector, because the sector also represented real estate companies in Port Mansfield. This issue was addressed as follows.

[58] Average revenue weighted by the number of fishing guides at each company.
[59] *Proprietary income* is defined as "payments received by self employed individuals as income." (IMPLAN Handbook)

Approximately half of the boat storage companies in Port Mansfield provided revenue and employment data to the research team. The other half provided only employment information. However, when the employment data was entered into IMPLAN, the revenue value generated significantly exceeded the revenues reported by the boat storage companies. The researchers calculated the average revenues of the three companies that provided both revenue and employment data. This average revenue value was subsequently used for each of the three boat storage companies that provided only employment data.

Appendix F: The Regional and Local Impacts of Texas Ports—Summary of Martin and Associates Studies

Martin and Associates is a highly reputable and experienced consulting company that has undertaken a majority of the U.S port impact studies over the last decade. In Texas, for example, it has performed economic impact analyses of eight major Texas ports in recent years. In alphabetical order they comprise Beaumont and Port Arthur, Brownsville, Corpus Christi, Freeport, Houston, Port Lavaca and Port Comfort, Texas City, and Victoria. As noted in the introduction to this report, the Texas Port Association requested that the researchers not undertake any input-output economic impact analysis as part of this study on those ports that recently sponsored work by Martin and Associates. They requested that the summary data from each Martin and Associates study be reported in the study and included in any products developed for the public use. In this report, the researchers have separated all Martin and Associates work from that they completed so that the separation is both obvious and transparent. The economic impact data reported in the following section is therefore a summary of recent Martin studies and does not represent original research by the CTR/TTI team. Readers seeking more information are requested to examine the web site of each port as many place such reports for public use. Further questions should be directed to staff at the port of interest and details are given at the end of this appendix.

Port of Beaumont

The Port of Beaumont is a large cargo port located approximately 84 miles east of Houston in Jefferson County. It is accessible from the Gulf Intracoastal Waterway through the Sabine-Neches ship channel. One of the greatest advantages of the location of the Port of Beaumont is that it is connected with the U.S. inland waterway system. Using this network, cargo transported by barge through the Port of Beaumont can be delivered to Minneapolis, Chicago, St. Louis, Kansas City, Louisville, Omaha, and Memphis.[60] Due to its strategic location, the Port of Beaumont is a valuable cargo and military port. The Port of Beaumont includes layberths for domestic ships as well as various facilities to accommodate the international and U.S. products that pass through the port. The main sources of revenue for the port are breakbulk and bulk cargo. The Port of Beaumont's principal trading partners are Brazil, Canada, Iraq, Russia, and China. The principal commodities shipped through the port are forest products, aggregate, ash products, and project and military cargo. Table F1 illustrates the economic importance of the ports to the local economy.[61]

[60] http://www.portofbeaumont.com
[61] Economic Impact of the Port of Beaumont. Martin Associates, 2006.

Table F1: Beaumont Port Values

JOBS	**3,730**
Direct Jobs	970
Induced Jobs	730
Indirect Jobs	165
Related Jobs	1,865
PERSONAL INCOME (in millions of US$)	**129.1**
Direct	45.2
Re-Spending / Consumption	77.7
Indirect	6.2
ECONOMIC VALUE (in millions of US$)	**122.2**
Direct Revenues	107.8
Local Purchases	14.4
TAXES (in millions of US$)	**34.8**
State and Local Taxes	11.6
Federal Taxes	23.2

Port of Brownsville

The Port of Brownsville provides a vital connection for trade between the United States and Mexico. It is located at the southernmost point of Texas in Cameron County, and it links Mexico's land transportation system to the United States' inland waterway system.[62] The chief products handled by the Port of Brownsville are petroleum products, ores and minerals, steel and other metals, vegetable oils, and grains. In addition its substantial trade with Mexico, the Port of Brownsville also has significant trading relationships with Central/South America, China, Korea, Japan, and Germany. In 2005, the Port of Brownsville handled over 4.5 million tons of cargo.[63]

Economic Impact

Table F2 illustrates the economic importance of the Port of Brownsville to the local economy. The jobs created and revenues and taxes generated by port-related companies in the Port of Brownsville are shown.[64]

[62] http://www.portofbrownsville.com
[63] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-5.
[64] The Local and Regional Economic Impacts of the Port of Brownsville. Martin Associates, 2006.

Table F2: Brownsville Port Values

JOBS	**38,429**
Direct Jobs	4,695
Induced Jobs	2,446
Indirect Jobs	3,437
Related Jobs	27,851
PERSONAL INCOME (in millions of US$)	**1,925.9**
Direct	140.8
Re-Spending / Consumption	198.7
Indirect	147.0
Related Income	1,439.4
ECONOMIC VALUE (in millions of US$)	**2,779.5**
Direct Revenues	515.7
Local Purchases	182.2
Related Output	2,081.6
TAXES (in millions of US$)	**173.6**
State and Local	44.1
Federal	129.5

* Includes marine terminals and shipyard/oil rig repair operations

Port of Corpus Christi

The Port of Corpus Christi is approximately 150 miles north of the U.S.-Mexico border in Nueces County. It includes a channel with a depth of 45 feet and over 295,500 square feet of covered dockside storage. Along with these shipping facilities, the Port of Corpus Christi provides easy access to both rail and highway transportation to assist with smooth transitions between transportation modes.[65] In addition to serving locations all over the United States, the Port of Corpus Christi trades with partners such as Venezuela, Nigeria, Mexico, Saudi Arabia, Columbia, Algeria, Kuwait, the United Kingdom, Australia and New Zealand. The primary imports in these trades are oil, feed stock, bauxite ore, naphtha, condensate, reformate, toluene, frozen beef and fresh fruit. The main exports at the Port of Corpus Christi are oil, gasoline, feed stock, diesel, alumina, petroleum coke, toluene, cumene gas, asphalt, and coal. Along with cargo trading, the Port of Corpus Christi has public and private oil docks, warehouses, grain terminals, cold storage, and other cargo-related facilities. In total, the Port of Corpus Christi handled nearly 87 million tons of cargo in 2005.[66] The Port of Corpus Christi is also a strategic port for military deployments.

Economic Impact

Table F3 illustrates the economic importance of the Port of Corpus Christi to the local economy. The jobs created and revenues and taxes generated by port-related companies in the Port of Corpus Christi are shown.[67]

[65] http://www.portofcorpuschristi.com
[66] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-7.
[67] The Local and Regional Economic Impacts of the Port of Corpus Christi. Martin Associates, 2004.

Table F3: Corpus Christi Port Values

JOBS	**40,883**
Direct Jobs	11,859
Induced Jobs	8,930
Indirect Jobs	19,116
Related Jobs	978
PERSONAL INCOME (in millions of US$)	**2,171.5**
Direct	555.8
Re-Spending / Consumption	686.4
Indirect	929.3
ECONOMIC VALUE (in millions of US$)	**2,762.7**
Direct Revenues	1,262.7
Local Purchases[a]	1,500.0
TAXES (in millions of US$)	**207.4**
State and Local Taxes	194.0
Custom Receipts	13.4

[a] includes port dependent businesses
* Includes marine terminals and non-cargo waterfront activity

The Port of Port Freeport (Brazos River Harbor Navigation District of Brazoria County, Texas)

The Port of Port Freeport is located approximately 50 miles Southeast of Houston in Brazoria County. The channel that proves access to the port is 400 ft wide and 45 ft deep. In addition to the facilities already in place, Port Freeport currently has more than 7,500 acres available for development, signaling possible economic growth in the future.[68] Port Freeport trades extensively with Nigeria, Saudi Arabia, South Africa, Brazil, Columbia, the Dominican Republic, Guatemala, Honduras, Mexico, Venezuela, and Costa Rica. The principal imports of Port Freeport are crude petroleum, containerized and palletized fruit, textiles, aggregate, paper goods and plastics. The primary exported commodities in Port Freeport include automobiles, chemicals, clothing, food, paper goods, and plastics. Port Freeport operated approximately 33.9 million tons of cargo in 2005. The development of LNG facilities along with the growth of containerized cargoes and breakbulk are driving the port's growth and strategic relevance.

Table F4 illustrates the economic importance of Port Freeport to the local economy. The jobs created and revenues and taxes generated by port-related companies in Port Freeport are shown.

[68] http://www.portfreeport.com

Table F4: Freeport Port Values

JOBS	**25,795**
Direct Jobs	8,090
Induced Jobs	8,116
Indirect Jobs	9,589
PERSONAL INCOME (in millions of US$)	**1,818.3**
Direct	495.6
Re-Spending / Consumption	852.7
Indirect	470.0
ECONOMIC VALUE (in millions of US$)	**1,558.9**
Direct Revenues	883.0
Local Purchases	675.9
Related Output	
TAXES (in millions of US$)	**169.9**
State and Local Taxes	163.6
Custom Receipts	6.3

*includes private and public terminals

Port of Houston (Port of Houston Authority)

The Port of Houston is one of the largest cargo ports in the United States. It is ranked first in the U.S. in foreign waterborne tonnage, and serves as Texas's only major container port. The Port of Houston is also the tenth largest port in the world in total tonnage. The port "includes a 25-mile-long complex of diversified public and private facilities."[69] The Port of Houston is also the second-largest cruise port in Texas and will become an even more important with the opening of the Bayport cruise terminal. Within the United States, the Port of Houston serves the "Midwest, Central, Southwest, and Western United States."[70] International trade partners of the Port of Houston include various countries in the Middle East, South America, Europe, and Mexico. The principal products handled at the Port of Houston include crude fertilizers, petroleum, organic chemicals, cereal, iron and steel, machinery, plastics and vehicles. In 2005, the Port of Houston handled over 34.5 million tons of cargo. The Port of Houston, because of its size and diversity, is one of the most vital cargo and transportation ports in Texas.[71]

Table F5 illustrates the economic importance of the Port of Houston to the local economy. The jobs created and revenues and taxes generated by port-related companies in the Port of Houston are listed in the table.

[69] http://www.portofhouston.com

[70] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-14.

[71] The Local and Regional Economic Impacts of the Port of Houston. Martin Associates, 2007.

Table F5: Houston Port Values

JOBS	**785,049**
Direct Jobs	58,142
Induced Jobs	61,714
Indirect Jobs	79,127
Related Jobs	586,066
PERSONAL INCOME (in millions of US$)	**$39,264.8**
Direct	$2,833.5
Re-Spending / Consumption	$7,448.7
Indirect	$3,148.0
Related Income	$25,834.6
ECONOMIC VALUE (in millions of US$)	**$117,589.5**
Direct Revenues	$8,084.6
Local Purchases	$5,912.9
Related Output	$103,592.0
STATE AND LOCAL TAXES (in millions of US$)	**$3,690.8**
Direct, Induced, and Indirect	$1,262.4
Related State and Local Taxes	$2,428.4

* includes public and private terminals

The Port of Port Lavaca–Point Comfort

The Port of Port Lavaca–Point Comfort is located close to the center of the Gulf Coast. It is the principle marine facility on the Matagorda Ship channel, which includes cargo handling facilities along with marinas and other recreational facilities.[72] Port Lavaca "plays a vital role in supporting Texas chemical manufacturing industries."[73] This is the main cargo activity at the Port of Port Lavaca–Point Comfort, where cargo is traded within the "Mid-Texas Coastal Region and South Western United States."[74] The Port also trades with the Caribbean, the Far East, Mexico and South America. This trade resulted in nearly 4.9 million tons of cargo handled by Port Lavaca in 2005.[1] One unique feature of the Port is the domination of exports over imports due to the high value chemicals produced in the surrounding area.[75]

Table F6 outlines the economic importance of the Port to the local economy. The jobs created and revenues and taxes generated by port-related companies in the Port Lavaca region are shown in the table.

[72] http://www.portlavaca.org
[73] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-17.
[74] Economic Impacts of the Port of Port Lavaca–Point Comfort and the Matagorda Ship Channel. Martin Associates, 2005.
[75] "Matagorda Ship Channel's Value to Texas & the Nation," Charles Hausemann, Presentation to Galveston District Dredging Conference, September 14, 2006. http://www.swg.usace.army.mil/OD/2006DC/Charles%20Hausemann%20-%20Port%20Lavaca%20Point%20Comfort%20-%202006%20Dredging%20Conference.pdf

Table F6: Port Lavaca Port Values

JOBS	**16,583**
Direct Jobs	5,300
Induced Jobs	4,590
Indirect Jobs	6,693
PERSONAL INCOME (in millions of US$)	**$988.1**
Direct	$273.0
Re-Spending / Consumption	$469.8
Indirect	$245.3
ECONOMIC VALUE (in millions of US$)	**$2,292.0**
Direct Revenues	$1,954.0
Local Purchases	$338.0
Related Output	
TAXES (in millions of US$)	**$266.7**
State and Local Taxes	$88.9
Federal Taxes	$177.8

*includes all vessel and cargo activity

Port of Texas City (Texas City Terminal Railway Company and Port of Texas City)

The Port of Texas City is the third largest cargo port in Texas, located approximately 10 miles Northwest of Galveston in Galveston County. One of the greatest advantages of the Port of Texas City is that it has a railway system that is highly integrated with its water transportation system.[76] This facilitates multi-modal movement of cargo including crude petroleum oil and refined petroleum products. The Port of Texas City includes 1500 acres of land leased "to various industrial entities that operate petrochemical plants and refineries and tank and terminal facilities."[77] This makes the Port of Texas City one of the most vital ports in petroleum transportation and refining. In 2005, the Port of Texas City handled over 60.5 million tons of cargo, and this number continues to increase every year. The regional and statewide impacts of the Port of Texas City, as reported in a report from Martin and Associates dated February 15, 2005 are presented in Table F7.

[76] http://www.railporttc.com
[77] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-24.

Table F7: Texas City Port Values

JOBS	**15,050**
Direct Jobs	4,452
Induced Jobs	4,293
Indirect Jobs	6305
PERSONAL INCOME (in millions of US$)	**$919.5**
Direct	$260.5
Re-Spending / Consumption	$448.1
Indirect	$210.9
BUSINESS REVENUE (in millions of US$)	**$4,169**
LOCAL PURCHASES	**$663.4**
TAXES (in millions of US$)	**$248.3**
State and Local Taxes	$82.8
Federal Taxes	$165.5

*includes all vessel and cargo activity

Port of Victoria (Victoria County Navigation District)

The Port of Victoria is located approximately 80 miles Northeast of Corpus Christi. Already a significant cargo port, recent expansions should significantly increase the tonnage operated by the port. The expansions included nearly doubling the size of the harbor and adding a 400 ft by 150 ft barge slip.[78] The Port serves all other ports along the Inland Waterway System within the United States. The main products traded at the port include chemicals and petrochemicals, sand and gravel, grain, project cargo and fertilizers. The Port of Victoria moved nearly 6.3 million tons of cargo in 2005.[79]

Table F8 demonstrates the economic importance of the Port of Victoria to the local economy. The jobs created and revenues and taxes generated by port-related companies in the Port of Victoria are outlined in the table.[80]

[78] http://www.portofvictoria.com
[79] Texas Ports 2007–2008 Capital Program, Texas Department of Transportation, page A-25.
[80] Economic Impacts of the Port of Victoria. Martin Associates, 2005.

Table F8: Victoria Port Values

JOBS	**9,235**
Direct Jobs	2,896
Induced Jobs	2,685
Indirect Jobs	3,654
PERSONAL INCOME (in millions of US$)	**587.3**
Direct	161.8
Re-Spending / Consumption	278.3
Indirect	147.2
ECONOMIC VALUE (in millions of US$)	**1,453.3**
Direct Revenues	1,228.5
Local Purchases	224.8
STATE AND LOCAL TAXES (in millions of US$)	**158.5**
State and Local Taxes	52.8
Federal Taxes	105.7

Texas Port Directory for Martin and Associates

Port of Beaumont (Port of Beaumont Navigation District of Jefferson County, Texas)
1225 Main Street
Beaumont, TX 77704
(409) 835-5367
www.portofbeaumont.com

Port of Brownville (Brownsville Navigation District)
1000 Foust Road
Brownsville, TX 78521
(956) 831-4592
www.portofbrownsville.com

Port of Corpus Christi (Port of Corpus Christi Authority)
222 Power Street
Corpus Christi, TX 78401
(361) 882-5633
www.portofcorpuschristi.com

Port of Port Freeport (Brazos River Harbor Navigation District of Brazoria County, Texas)
200 W. Second St.
P.O. Box 615
Freeport, TX 77542
(979) 233-2667
www.portfreeport.com

Port of Houston (Port of Houston Authority)
111 East Loop North
Houston, TX 77029
(713) 670-2400
www.portofhouston.com

Port of Port Lavaca–Point Comfort (The Port of Lavaca–Point Comfort)
P.O. Box 397
Point Comfort, TX 77978
(361) 987-2813
www.portofplpc.com

Port of Port Arthur (Port of Port Arthur Navigation District of Jefferson County)
P.O. Box 1428
221 Houston Avenue
Port Arthur, Texas 77641
(409) 983-2011
www.portofportarthur.com

Appendix G: Container Forecasting Appendix

1. Introduction

One of the objectives of the research study was to forecast the number of container TEUs (both import and export combined) at the port of Houston at a future point in time. This information is important for, among other reasons, to determine capacity expansion requirements and to investigate required changes in port operation policies.

The number of containers that a port handles depends mainly on the characteristics of the port's hinterland, the port's infrastructure, technological investments, and the operational policies adopted by the port, as well as global trade and economic trends. The characteristics of the port's hinterland could be described by population (county or state) variables, the population growth rate employment/unemployment rate, the Gross State Product (GSP), total number of workers in services, etc., while the global trade and economic trends can be captured by import/export price indices and the national/continental share of containers handled by the port. However, the explanatory variables used in this study were limited to the data available.

Time series data for the dependent variable (i.e., total annual number of container TEUs handled by the port of Houston) was available for a period of about 35 years (i.e., 1970-2004). However, a regression model with 35 data points may not produce efficient estimates of the parameters. Hence, the researchers pooled together similar time series data from several other U.S. ports to create a sizeable panel dataset to ensure the, efficient estimation of the parameters. However, as mentioned earlier, the number of containers handled by a port depends to some extent on several variables specific to the port. A model that pools together the data from several ports may thus not be able to capture the effects that are specific to individual ports. This heterogeneity across different ports was accounted for by the sophisticated panel data models used in this study. These models thus addressed the problem of too few data points by pooling time series data for several ports and incorporated the effects specific to individual ports.

This appendix describes section the data used in the models, discusses the methodology, provides the results of the models, and estimates the annual number of container TEUs until 2025 for the port of Houston.

2. Data Description

The dependent variable in all the models was the annual container counts at nine different U.S. ports from 1984 to 2005 (i.e., 22 observations at each port)[81].

The nine ports were:

- Miami,
- Honolulu,
- Houston,
- Savannah,
- Charleston,

[81] The pooled panel data hence consisted of 198 total observations, corresponding to 22 observations at each of the nine ports.

- Tacoma,
- Seattle,
- Oakland, and
- Hampton Roads.

The independent variables included:

- the annual population estimates for 1984 to 2005 of the counties in which the ports reside,
- the annual Gross State Product (GSP) of the states in which the ports reside from 1984 to 2005,
- the U.S. population estimates from 1984 to 2005, and the
- Import Price Index (IPI) of all commodities from 1984 to 2005.

3. Methodology

Several regression models were estimated using the panel data described earlier. The basic framework for all the models was a regression equation of the form:

$$y_{it}=\mathbf{x_{it}}'\boldsymbol{\beta}+\mathbf{z_i}'\boldsymbol{\alpha}+\boldsymbol{\varepsilon_{it}} \qquad \textbf{(1)}$$

where, t refers to the year of the observation, and i refers to a specific port. There are four regressors (i.e., county population, U.S. population, GSP, and IPI) in $\mathbf{x_{it}}$ (without a constant). The individual effects of the port (heterogeneity) are captured by the term $\mathbf{z_i}'\boldsymbol{\alpha}$**,** which contains a constant term and which can also contain a set of port-specific observed and unobserved variables. The parameters of this model can be estimated by ordinary least squares (OLS) estimation if all the variables in $\mathbf{z_i}'$ can be observed. However, this is seldom the case, necessitating the use of a simple pooled OLS model or more complicated models, such as the fixed effects models, random effects models, and covariance structure models, to estimate the parameters.

3.1 Pooled OLS Model

The simplest model for estimating the parameters in the earlier mentioned regression equation is to assume that $\mathbf{z_i}$ contains only a constant term. Hence, an ordinary least square (OLS) regression estimation on the pooled data can provide consistent and efficient estimates of the parameters. The OLS regression model was estimated on the pooled data considering all 198 observations. The parameters were assumed to be the same for all the ports.

3.2 Least Squares Dummy Variables (LSDV) Model

The estimation of the Least Squares Dummy Variables (LSDV) model is similar to that of the OLS model described earlier. The formulation is, however, different in that it is assumed that the variation across different ports is captured by differences in the constant terms. Hence, the LSDV model estimates nine different parameters for the constants of the nine different ports. If y_i represents the time-series vector of the dependent variable y from port i, and X_i represents the time-series vector of the explanatory variables of the corresponding port i, and the constant parameter for port i is defined by α_i, then the model can be formulated as:

$$\begin{vmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_n \end{vmatrix} = \begin{vmatrix} X_1 \\ X_2 \\ . \\ . \\ . \\ X_n \end{vmatrix} \beta + \begin{vmatrix} I & & & & \\ & I & & 0 & \\ & & . & & \\ & & & . & \\ & 0 & & . & \\ & & & & I \end{vmatrix} \begin{vmatrix} \alpha_1 \\ \alpha_2 \\ . \\ . \\ . \\ \alpha_n \end{vmatrix} + \begin{vmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ . \\ \varepsilon_n \end{vmatrix} \quad \textbf{(2)}$$

where, I is an identity matrix of size 22. Assembling these matrices results in

$$y = X\beta + D\alpha + \varepsilon \quad \textbf{(3)}$$

The parameters of this equation can then be estimated using the OLS estimation method. Overall, this model is better than the pooled OLS model. However, the error distributions are still assumed to be uncorrelated and independent and identically distributed (i.i.d.). This assumption is relaxed in the subsequent models.

3.3 Random Effects GLS (RE Model)

The random effects Generalised Least Squares (GLS) model is different from the LSDV model in the treatment of the constant terms and error terms. Instead of constants specific to each port as in the case of the LSDV model, only one constant—considering the average effect over pooled data—is estimated and the differences across the ports are considered in the error terms. The following equation describes this formulation:

$$y_{it} = x_{it}{}' \beta + (\alpha + u_i) + \varepsilon_{it} \quad \textbf{(4)}$$

Here, the constant α represents the mean of the unobserved heterogeneity and u_i is the random component of heterogeneity, which is constant for a given port. Further, by considering $u_i + \varepsilon_{it}$ as the new error term and by assuming

$$\begin{aligned} &E[\varepsilon_{it} \mid X] = E[u_i \mid X] = 0 \\ &E[\varepsilon_{it}^2 \mid X] = \sigma_\varepsilon^2 \\ &E[u_i^2 \mid X] = \sigma_u^2 \\ &E[\varepsilon_{it} u_j \mid X] = 0, \quad \textit{for all} \quad i,t,j \\ &E[\varepsilon_{it}\varepsilon_{js} \mid X] = 0 \quad \textit{if } t \neq s, \quad i \neq j \\ &E[u_i u_j \mid X] = 0 \textit{if} \quad i \neq j \end{aligned} \quad \textbf{(5-10)}$$

the error covariance matrix is obtained as:

$$\Omega = \begin{vmatrix} \Sigma & & & & \\ & \Sigma & & 0 & \\ & & . & & \\ & & & . & \\ & 0 & & . & \\ & & & & \Sigma \end{vmatrix}, \quad where \tag{11}$$

$$\Sigma = \begin{vmatrix} \sigma_\varepsilon^2 + \sigma_u^2 & \sigma_u^2 & \sigma_u^2 & . & . & \sigma_u^2 \\ \sigma_u^2 & \sigma_\varepsilon^2 + \sigma_u^2 & . & . & \sigma_u^2 & \sigma_u^2 \\ \sigma_u^2 & . & . & . & . & . \\ . & . & . & . & . & . \\ . & \sigma_u^2 & . & . & . & . \\ \sigma_u^2 & \sigma_u^2 & . & . & . & \sigma_\varepsilon^2 + \sigma_u^2 \end{vmatrix} \tag{12}$$

For this error covariance matrix, the GLS estimate is given by,

$$\hat{\beta} = (X'\Omega^{\ 1}X)^{\ 1}X'\Omega^{\ 1}y \tag{13}$$

However, this model does not account for autocorrelation. However, autocorrelation can be considered [82] and is included in this study in the specification of the RE-AR model discussed in subsequent sections.

3.4 Covariance Structures

The modeling context of covariance structures differs from the modeling frameworks discussed earlier. A common conditional mean function is defined across the groups in covariance structures, and hence heterogeneity takes the form of different variances rather than shifts in the means. The correlation across different ports thus became a part of the model specification. All the data is pooled similar to an OLS model and the errors are assumed to be correlated across panels—different from OLS estimations. The equations are formulated as:

$$\begin{vmatrix} y_1 \\ y_2 \\ . \\ . \\ . \\ y_n \end{vmatrix} = \begin{vmatrix} X_1 \\ X_2 \\ . \\ . \\ . \\ X_n \end{vmatrix} \beta + \begin{vmatrix} \varepsilon_1 \\ \varepsilon_2 \\ . \\ . \\ . \\ \varepsilon_n \end{vmatrix} \tag{14}$$

Assuming,

[82] Autocorrelation can be introduced in the AR(1) process.

$$E[\varepsilon_i \mid X] = 0, and$$
$$E[\varepsilon_i \varepsilon_j^{'} \mid X] = \sigma_{ij}\Omega_{ij} \,, \qquad \textbf{(15)}$$

The error covariance matrix is obtained as,

$$\Omega = \begin{vmatrix} \sigma_{11}\Omega_{11} & \sigma_{12}\Omega_{12} & . & . & . & \sigma_{1n}\Omega_{1n} \\ \sigma_{21}\Omega_{21} & \sigma_{22}\Omega_{22} & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ \sigma_{n1}\Omega_{n1} & . & . & . & . & \sigma_{nn}\Omega_{nn} \end{vmatrix} \qquad \textbf{(16)}$$

Given this, a GLS estimation can be used. Several models can be obtained by different specifications of Ω_{ij}, the simplest being Ω_{ij}=I. However, given autocorrelation and heteroskedasticity, several variations of this model can be specified. In this study, heteroskedastic with correlation across panels and autocorrelated (cov 1 model), and heteroskedastic without correlation across panels and autocorrelated (cov 2 model) are considered.

Exponential formulations of the six model specifications discussed in this appendix, were also tested. However, these models did not perform better and are therefore not discussed further. The next section provides the empirical results of the six model specifications.

4. Empirical Results

4.1 Pooled Data OLS Model: (POLS Model)

The estimation results of the pooled OLS model and the relevant model statistics are summarized in Table G1 and G2.

Table G1: Estimated POLS Model Parameters

	Coefficients	*Standard Error*	*t Stat*
Intercept	-3332217	300300.9	-11.0963
County population	-0.13672	0.026145	-5.22939
Gross State Product	0.550514	0.078782	6.987829
Import Price Index	3529.463	3905.628	0.903686
US Population	0.015062	0.001785	8.44001

Table G2: POLS Model Statistics

Regression Statistics	
Multiple R	0.805548
R Square	0.648907
Adjusted R Square	0.64163
Standard Error	285636.3
Observations	198

The t-statistics for all the coefficient estimates other than IPI are greater than the 90 percent confidence critical t-value of 1.64, indicating the statistical significance of these variables. However, it was decided to retain IPI in all further models. The R squared value of about 0.66 indicates a relatively good fit of the data.

4.2 Least Squares Dummy Variables Model (LSDV Model)

The estimation results of the LSDV model and the model statistics are presented in Table G3 and G4.

Table G3: Estimated LSDV Model Parameters

	Coefficients	*Standard Error*	*t Stat*
County population	-0.35192	0.105707	-3.32921
Gross State Product	0.296188	0.120088	2.466428
Import Price Index	3688.122	1952.136	1.889275
US Population	0.017666	0.00109	16.20442
Intercept specific to Miami	-3780096	231009.9	-16.3634
Intercept specific to Honolulu	-4138399	217081.9	-19.0638
Intercept specific to Houston	-3278264	293820.8	-11.1574
Intercept specific to Savannah	-4216750	210000.7	-20.0797
Intercept specific to Charleston	-3824125	215554.3	-17.7409
Intercept specific to Tacoma	-3713621	206515.7	-17.9823
Intercept specific to Seattle	-3172328	225953.9	-14.0397
Intercept specific to Oakland	-3386995	158677.6	-21.3451
Intercept specific to Hampton Roads	-3742313	203675.6	-18.3739

Table G4: LSDV Model Statistics

Regression Statistics	
Multiple R	0.991761
R Square	0.983591
Adjusted R Square	0.977121
Standard Error	142655.8
Observations	198

This model shows an improved fit of the data compared to the POLS model, as is evident from the R squared value of 0.98 as compared to the R squared value of 0.64 for the POLS model. Furthermore, the t-statistics of all the parameter estimates are greater than the critical t-value of 1.645 at the 90 percent confidence level. Hence, all the variables are statistically significant. Heterogeneity among the ports is captured by the different values of the intercepts for the individual ports.

4.3 Random Effects GLS Model (RE Model)

The estimation results of the random effects GLS model (RE model) and relevant model statistics are provided in Table G5 and G6.

Table G5: Estimated RE Model Parameters

	Coefficients	*Standard Error*	*t Stat*
Intercept	-3692192	223232.9	-16.54
County population	-.252802	.0829682	-3.05
Gross State Product	.2802107	.1140091	2.46
Import Price Index	3614.867	1952.59	1.85
US Population	.0172437	.0010645	16.20

Table G6: RE Model Statistics

Regression Statistics	
σ_u	323662.88
σ_ε	142655.76
Adjusted R Square	0.553
Observations	198

From Table 5 it is evident that all the parameters have t-statistics greater than the 90 percent critical t-value of 1.645 and are therefore all statistically significant at the 90 percent confidence level. However, autocorrelation is not accounted for in this model.

4.4 Random Effects GLS Model with Autocorrelation (RE-AR Model)

The estimation results of the random effects GLS model with autocorrelation (RE-AR model) and the model statistics are given in Table G7 and G8.

Table G7: Estimated RE-AR Model Parameters

	Coefficients	*Standard Error*	*t Stat*
Intercept	-3589457	365793.5	-9.81
County population	-.1850839	0.088	-2.11
Gross State Product	.4222484	0.175	2.41
Import Price Index	5448.744	2139.233	2.55
US Population	.0158183	0.0011	16.20

Table G8: RE-AR Model Statistics

Regression Statistics	
σ_u	231024.84
σ_ε	97102.04
Adjusted R Square	0.63
ρ	0.76
Number of observations	198

Note: p is the autocorrelation coefficient

Compared to the RE-model, the adjusted R squared value indicate an improved fit of the RE-AR model over the RE model. Again, all the parameter estimates have t-statistics greater than the critical t-value at the 90 percent confidence interval, and are therefore all statistically significant.

4.5 Covariance Structures-Heteroskedastic with Correlation across Panels and Autocorrelated (cov1 model)

The estimation results of the Cov1 model (covariance structures—heteroskedastic with correlation across panels and autocorrelated) and the relevant model statistics are provided in Table G9 and G10.

Table G9: Estimated Cov1 Model Parameters

	Coefficients	*Standard Error*	*t Stat*
Intercept	-2591715	368108.2	-7.04
County population	-.1527337	.0228107	-6.70
Gross State Product	.3301078	.05902881	5.59
Import Price Index	1843.547	1996.202	0.92
US Population	.0133721	.0016755	7.98

Table G10: Model Statistics

Estimated covariances = 45	Number of obs = 198
Estimated autocorrelations = 9	Number of groups = 9
Estimated coefficients (Log likelihood = -2495.962) = 5	Time periods = 22

This specification resulted in the t-statistic for the IPI parameter to be less than the 90 percent confidence critical t-value of 1.645, indicating that this variable is not statistically significant.

4.6 Covariance Structures-Heteroskedastic without Correlation across Panels and Autocorrelated (cov2 model)

Table G11 and G12 summarize the estimated model parameters and statistics, respectively, of the covariance structures—heteroskedastic without correlation across panels and autocorrelated (cov2 model).

Table G11: Estimated Cov2 Model Parameters

	Coefficients	*Standard Error*	*t Stat*
Intercept	-3711987	310062.9	-11.97
County population	-.1989041	.031898	-6.24
Gross State Product	.5291485	.0953041	5.55
Import Price Index	5735.73	1807.053	3.17
US Population	.016323	.0014304	11.41

Table G12: Model Statistics

Estimated covariances = 9	Number of observation = 198
Estimated autocorrelations = 9	Number of groups = 9
Estimated coefficients (Log likelihood = -2541.289) = 5	Time periods = 22

This specification resulted in the t-statistics of all the parameter estimates being greater than the 90 percent confidence critical t-value of 1.645, indicating that all the variables are statistically significant. Based on a comparison of the log-likelihood statistic, the cov1 model provides a better fit than the cov2 model.

5. Container Forecasts

The actual and predicted container counts and the percentage deviation between the actual and predicted container counts for the port of Houston, from 1984 to 2005 are graphed in Figure G1 and G2. The container forecasts for the port of Houston, as predicted by the six models, from 2005-2025, are graphed in Figure G3. Table G13 provides both the actual and predicted container counts (by each of the models) from 1984 to 2025. From Figures G1 and G2 it is evident that RE model's prediction deviate the most from the actual data compared to the other five models, and can thus be discarded. The POLS and RE-AR models vary slightly with R squared values of 0.65 and 0.63, respectively. However, these models are more efficient in terms of the estimated parameters compared to a model with only Houston data, because of the additional data (i.e., N=198 compared N=22).

The POLS and Cov2 models predict container counts exceeding 3,000,000 for the year 2020. However, the actual annual container count from 2001 to 2005 and thus the growth rate of containers, (i.e., the average slope of the line from 2001 to 2005) is very high. All the models predict a lower growth rate of containers in this period. If the growth trend of 2001 to 2005 continues into the future, all the models will underestimate the container counts. These model estimates can thus be used to provide lower bounds for future container prediction scenarios.

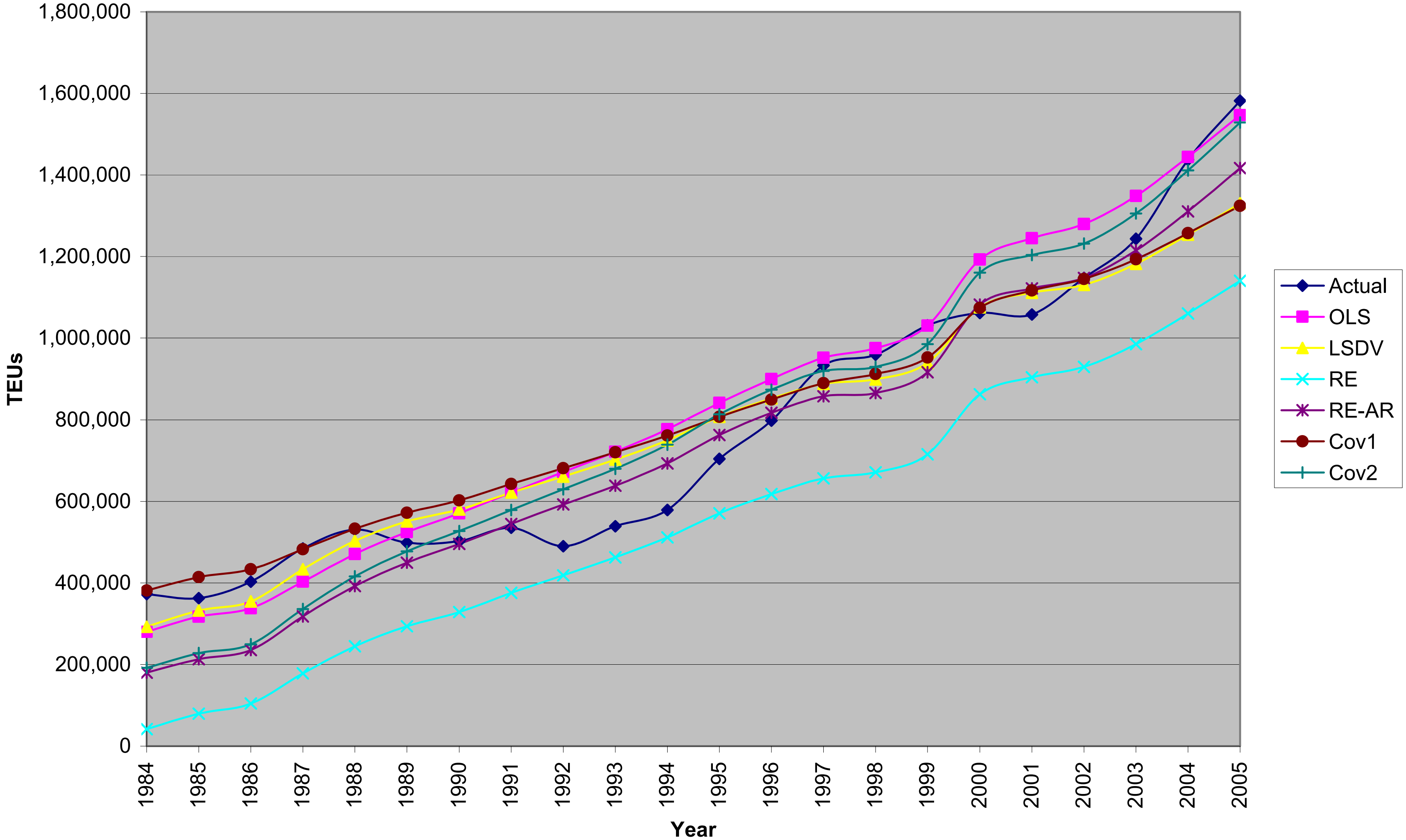

Figure G1: Houston Container Count Predictions of the Six Models (1984-2005)

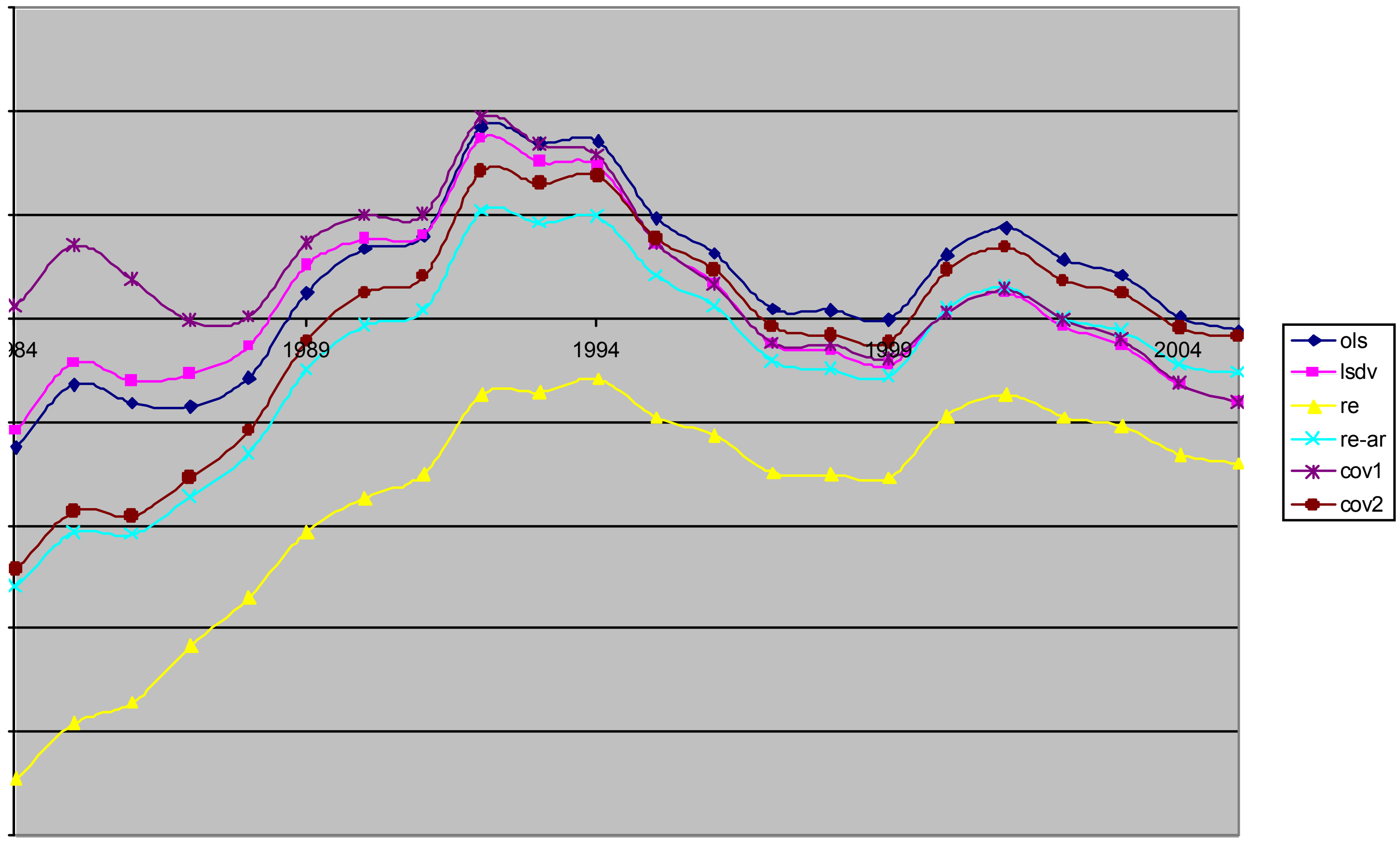

Figure G2: Percent Deviation of the Six Models from Actual Container Counts (1984-2005)

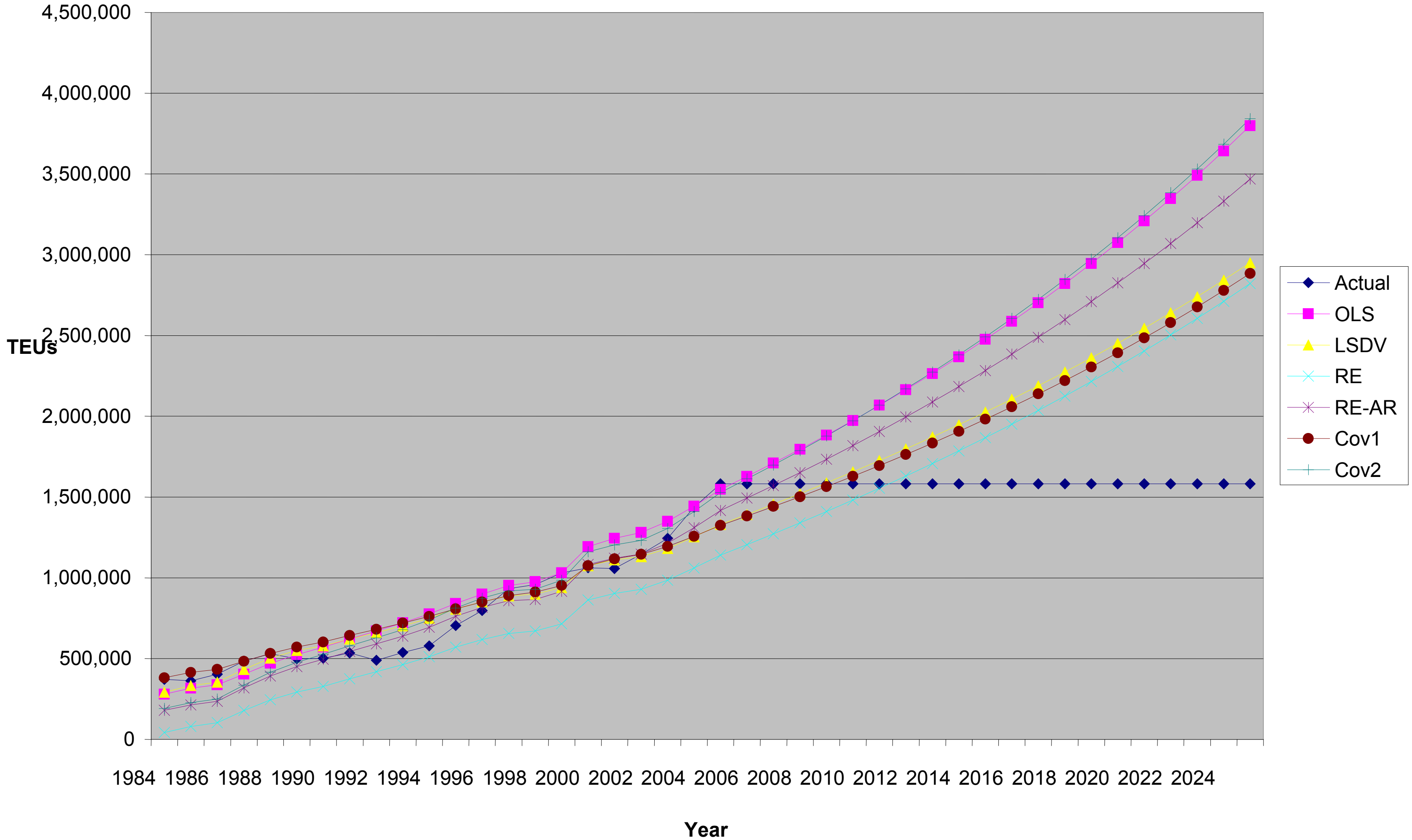

Figure G3: Predicted Container Counts by the Six Models (1984-2025)

Table G13: Actual and Predicted Container Count (TEUs) by Model (1984-2025)

Year	Actual	OLS	LSDV	RE	RE-AR	Cov1	Cov2
1984	372,280	279907.4	292317.4	41696.58	179872.2	381425.3	192033
1985	362,728	317078.8	332002.9	79312.23	213218.6	414036.7	228105.3
1986	402,972	337613.9	354228.7	104310.7	235303.4	433483.2	249317.9
1987	484,585	403046.8	433342	178320.8	317817	482631.3	335920
1988	530,593	470399.5	503013.6	244749.1	392466.3	532463.3	416312.5
1989	498,841	524386.7	550506.6	293963.8	449557.8	571712.5	477467.2
1990	502,035	570520.6	579737.8	328569.6	495514.8	602133.9	527417.5
1991	535,112	621585.2	621834	375459.1	544530.6	642771.5	578889
1992	490,106	671748.6	660914.2	418796	592225.6	680963.9	629870.3
1993	538,732	721704.1	702436.1	462735.7	638343.9	720087	679642.7
1994	578,693	776781.2	749236.6	511470.4	693013.6	761148	738660.3
1995	704,010	841411.9	807069.1	570457.4	762634.9	807334.5	813492.8
1996	797,713	899575.9	852396.7	617914.5	817216.6	849671.1	873596.5
1997	933,522	951876.9	887878.1	656155.6	857740.8	889597.8	919666.1
1998	959,127	975488.9	898841	671291.5	865770.4	912368.2	929365.3
1999	1,031,071	1030394	939703.7	715223.9	916615.6	952252.8	985257.5
2000	1,061,525	1192887	1075553	862376	1081947	1074241	1160688
2001	1,057,869	1244831	1111460	903868.6	1121756	1117017	1204043
2002	1,147,489	1279762	1130521	929619.6	1147607	1145188	1231790
2003	1,243,866	1348609	1182248	985457.4	1215123	1193624	1305478
2004	1,437,585	1443915	1253830	1060242	1310553	1257436	1411074
2005	1,582,081	1546899	1330541	1140651	1416944	1324275	1528595
2006	-	1627086	1392428	1205681	1492964	1381952	1612288
2007	-	1709738	1455804	1272211	1571047	1441191	1698436
2008	-	1794975	1520735	1340304	1651288	1502068	1787154
2009	-	1882925	1587292	1410028	1733788	1564659	1878568
2010	-	1973725	1655549	1481455	1818654	1629046	1972808
2011	-	2067518	1725584	1554661	1905996	1695316	2070015
2012	-	2164455	1797479	1629724	1995935	1763561	2170335
2013	-	2264696	1871324	1706730	2088595	1833877	2273924
2014	-	2368413	1947209	1785767	2184110	1906367	2380945
2015	-	2475783	2025234	1866928	2282618	1981138	2491574
2016	-	2586997	2105500	1950315	2384268	2058307	2605993
2017	-	2702256	2188119	2036030	2489217	2137994	2724397
2018	-	2821772	2273204	2124186	2597630	2220326	2846993
2019	-	2945771	2360879	2214900	2709683	2305440	2973996
2020	-	3074490	2451274	2308294	2825560	2393479	3105639
2021	-	3208182	2544523	2404502	2945458	2484594	3242164
2022	-	3347113	2640774	2503660	3069583	2578947	3383829
2023	-	3491565	2740178	2605915	3198155	2676708	3530907
2024	-	3641837	2842898	2711423	3331405	2778055	3683687
2025	-	3798246	2949105	2820346	3469579	2883179	3842474