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Economic Benefits of Productivity Increases through Truck-to-Rail Mode Shift in Freight Transport

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TECHNICAL SUMMARY

Title

Economic Benefits of Productivity Increases through Truck-to-Rail Mode Shift in Freight Transport

Introduction

Although the study of economic benefits of improving (or not improving) the efficiency of freight movement has been recognized as one of the critical research topic by the decision makers and researchers alike, there remains a dearth of transparent and theoretically sound method to actually estimate the impacts. While there are many factors, the lack of reliable tools to simulate how the efficiency changes affect the flow of goods and also the absence of the framework to translate the output into an economic impact measure are two major obstacles. This study applies a Computable General Equilibrium (CGE) model for the Chicago region to analyze the impacts of productivity increase in the trucking sector.

Approach and Methodology

The Computable General Equilibrium (CGE) models address one of the major weaknesses of the input-output models that are commonly used to estimate economic impacts of transportation projects by endogenously incorporating equilibrium prices into the model. The CGE model used in this study is derived from the Chicago-CGE model developed in an earlier effort at the University of Illinois at Chicago's Urban Transportation Center (UTC). The C-CGE model is a static model that represents the economy of the 6-county Chicago region. For this project, the C-CGE's economic sectors had to be reduced from 25 to 12 in order to analyze two scenarios that hypothesize plausible effect of a shift of freight traffic from truck to rail for the Chicago region. The first scenario focuses on the positive benefit of greater productivity in trucking industry that can result from less congested roads and also being able to take on high-valued commodity. The second scenario looks at the negative impact associated with the decrease in the capital and labor inputs for trucking. In other words, the first scenario essentially hypothesizes that the output of the trucking sector can be increased while employing the same level of capital and labor. This corresponds to the situation that due to the mode shift from truck to rail, congestion is reduced and possibly better business environment for the trucking sector allows the firms to focus on higher value shipments. The second scenario assumes that more efficient operation of the trucking sector and expanding role of rail freight reduces the factor inputs for the trucking sector.

Findings

The result of the simulation of scenario in which trucking sector increases productivity by 20% is a 1.09% change in real gross regional product (RGRP) and value-added gross regional product (GRPVA). The second simulation analyzed reduced requirement for capital and labor cost due to larger mode share of rail. The results of this simulation are a -0.32% change in both RGRP and GRPVA.

Conclusions

This project demonstrated the feasibility of applying CGE models to evaluate the impacts of changes in productivity or output that may result from the mode shift between truck and rail. Compared against the Input-Output Models that are often used in economic impact studies, the CGE models are able to capture the effect of operating efficiency of the trucking sector. Our analysis indicates that increased productivity of trucking sector can produce considerable increases in the regional economy while the effect of decreases in the factor inputs to the trucking sector results in a modest decrease in the regional economy.

Recommendations

The results underscore the need for further effort to develop sophisticated analytical tools to evaluate the impacts of infrastructure investments and/or policies that promote a better balance of freight traffic among the modes.

Publications

Elizabeth Fu. *Evaluating the Economic Impact of Freight Investment in Chicago Using Computable General Equilibrium.* Master's Thesis. University of Illinois at Chicago. 2012

Alexandra McNally. *Intermodal Logistics Centers and Their Impact on Transportation Corridor Industrial Property Value.* Master's Thesis. University of Illinois at Chicago. 2014

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I. INTRODUCTION

A. Background

Freight transportation is a tremendous job generator for the nation, directly employing 7.8 million people, or 5.8% of the entire workforce in the U.S.[i] In some regions, such as Chicago, freight industry accounts for over 10% of the employment[ii]. For many communities that have lost manufacturing jobs, freight industry is regarded as the potential economic base for the future. The employment matrix for 2020, published by the Bureau of Labor Statistics[iii] forecasted that, nationally, employment in the transportation industry is expected to increase by 14.7% between 2010 and 2020, adding more than 1.3 million jobs in the U.S.

Freight transportation and its movement of goods are important components of the United States economy. The trucking industry's economic relationship is diverse because it interacts with a variety of other industries and represents a fair share of gross domestic product (GDP) (Boyer & Burks, 2009). A threat to the mobility of goods is congestion, particularly roadway congestion. A 2001 United States Department of Transportation (USDOT) study found that delays in trucking resulted in an increase of 50 to 250 percent in the cost of moving goods (U.S. Department of Transportation, Federal Highway Administration, 2002). Alleviating congestion is an important priority, especially for industries heavily dependent on road transportation as they are more sensitive to congestion and are more likely to benefit from less congested roads (Fernald, 1999; Shirley, 1999). The Federal Highway Administration found that the national trucking demand with respect to price is -0.97. While the study found that trucking demand is not very responsive to prices, the study also found that the demand elasticity with respect to truck delay is almost perfectly inelastic (HLB Decision Economics, 2008).

The relationship between freight transportation and congestion is an important issue, especially in Chicago. In terms of size, Illinois ranks fourth in the nation with nearly 139,000 miles of public roadway (Bureau of Transportation Statistics, 2010). Despite Illinois' infrastructure supply, Chicago represents an area where roadway demand is so great that the city in 2011 ranks as the second most congested urban area in the country (Schrank, Lomax, & Eisele, 2011). In 2006, three of top 35 worst trucking bottlenecks in the country,[1] amounting to 2.778 million hours in annual delay for trucks alone, were located in Chicago (Cambridge Systematics, Inc., 2008). Travel delay and excess fuel consumption cost the average Chicago commuter over $1,500 in 2011 (Schrank, Lomax, & Eisele, 2011). These factors serve as support that there is a need for transportation investment to alleviate congestion in Chicago.

While there are many studies citing the need for freight investment, the results of past research suggest varying impacts. Common methods to evaluate freight investments are cost-benefit analyses (CBA) and input-output (I-O) models. As discussed later, these methods often focus on

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[1] The bottlenecks include fifth ranked I-80 at I-94 split in Chicago, Illinois, ninth ranked I-90 at I-94 Interchange ("Edens Interchange"), and 31st ranked I-94 (Dan Ryan Expressway) at I-90 Skyway.

freight providers and freight users, failing to capture the overall aggregate economy (Halpern-Givens, 2010). Alternatively, computable general equilibrium (CGE) models capture the circular flow of income and expenditures of industries, government, and households. Compared to conventional analyses and models such as CBA and I-O models, CGE models, at least in theory, capture additional demand and depict a more realistic economy with the direct inclusion of households. CGE models reflect the circular flow of income and expenditures. They directly capture spending by not only industries, but government and households as well (Lusby, 2004). Because of its circular flow of income and expenditures of industries, government, and households, compared to conventional analysis and models, CGE can capture additional benefits of freight investment through price and productivity changes. Price is modeled endogenously. Prices are calculated to maximize gross domestic product and standard economic assumptions. Unlike I-O, prices can be analyzed to show how changes in prices can affect flows of goods and services. Additionally, productivity can be captured and explored within CGE using factor productivity. Productivity can be analyzed from the perspective of efficiency gains or the use of factor inputs.

This study applies a CGE model for the Chicago region to analyze the impacts of a mode shift from truck to rail. The CGE models address one of the major weaknesses of the input-output models that are commonly used to estimate economic impacts of transportation projects by endogenously incorporating equilibrium prices into the model. Several CGE models of the U.S. economy have been developed since the 1970's[iv]. However, some are "stylized" models with only a very simple structure and industry definitions that will not be appropriate for this study. Even the "applied" CGE models that have been developed for policy analysis tend to focus on trade policy issues, e.g. NAFTA, trade agreements, and they cannot be used for the present study without a major modification. In general, a specialized CGE model must be developed for analyzing a specific issue at hand. This study's goal is to develop an analytical framework to apply the CGE model in the analysis of freight mode shifts through the simulations of plausible impacts of such change. It should be noted that the framework developed in this study can also be applied to the analysis of the effects of fuel price increase or policy measures such as carbon tax.

II. LITERATURE REVIEW

This review of relevant literature proceeds in four sections. The first section discusses the existing empirical work evaluating the relationship between productivity and public infrastructure investment. The second section provides an overview of the framework behind CGE, its assumptions, and criticisms of CGE modeling. The third section reviews existing literature on CGE analysis as it applies to this study. The final section provides possible implications of this study given the review of existing research.

A. Productivity and Infrastructure Investment

The national economic slowdown in the 1970s and 1980s sparked an interest in the relationship between public infrastructure investment and productivity. The basic approach to capturing this relationship empirically is using the Cobb-Douglas production function. Aschauer (1989) spurred a debate when his study using a Cobb-Douglas production function found a strong private sector output level with respect to public capital. Using data from 1949 to 1985, he analyzed nonmilitary public capital stock and found a positive relationship between the ratio of public to private capital stock and total factor productivity (TFP). Specifically, he found a 1% increase in the public-private capital stock ratio results in a total factor productivity increase of 0.39% (Aschauer, 1989). Munnell (1989) furthered Aschauer's findings and contend that the decline of public infrastructure investment is the reason for the observed labor productivity declines. She found that public capital had a statistically significant impact on private sector output and public capital had a positively significant impact private sector employment on the state-level (Munnell & Cook, 1990). Both Aschauer and Munnell's findings drew criticisms. Some researchers argue the specifications used, such as estimated elasticities and implied marginal productivity of public capital as being too high (Nadiri & Mamuneasc, 1998). There were also questions about causation and the failure to address how public infrastructure capital and productivity growth could both affect each other (Nadiri & Mamuneasc, 1998; Shirley, 1999).

Other researchers, including Hulten and Schwab (1984, 1991), Holtz-Eakin (1994) and Evans and Karras (1994), disagree with Aschauer and Munnell's strong results as they found a minimal impact of public capital on productivity gains. Specifically focusing on manufacturing, Hulten and Schwab (1984) found evidence against the notion that the aging public infrastructure is the cause of the decline of manufacturing in the Snowbelt region of the U.S. They used a Hicks-neutral production function which assumes that output is a function of capital, labor, intermediate input, and an augmented value-added technical change. Analyzing the growth rates of these factors between 1951 and 1978, they observed little difference in TFP among all regions in the U.S. Between 1965-1973 and 1973-1978, TFP was declining in almost every region of the U.S. They found little evidence to suggest that a lack of public investment in the Snowbelt region was negatively affecting the manufacturing industry's TFP (Hulten & Schwab, 1984). When the pair later expanded their analysis through 1986, they again found that public investment did not significantly explain the success of manufacturing in the Southern and Western regions of the U.S. (Hulten & Schwab, 1991).

Hulten and Schwab's analysis also sparked criticism for failing to directly measure public infrastructure in their work. In response to Hulten and Schwab's work, Garcia-Mila and McGuire (1992) used a Cobb-Douglas production function that includes public investment inputs to compare the impact of public and private inputs across the entire economy, rather than focusing on one sector. Garcia-Mila and McGuire included variables such as capital in structures, capital in equipment, labor, highway capital, and education expenditures for the 48 contiguous states between 1969 and 1983. Their results showed highway and education expenditures as having a positive correlation with private output, with education having a stronger impact (Garcia-Mila & McGuire, 1992).

Holtz-Eakin (1994) attempted to reconcile the disparate findings of Hulten and Schwab (1984, 1991) and Garcia-Mila and McGuire (1992) among others. Holtz-Eakin (1994) evaluated the impacts of public investment on productivity by controlling for unobserved, state-specific characteristics in the production function. Using data from the 48 contiguous states between 1969 and 1986, he found that both at the state and regional levels, the elasticity for private output with respect to public capital is approximately zero (Holtz-Eakin, 1994). Using a similar dataset as Holtz-Eakin, Evans and Karras (1994) investigated the productivity of public investment for a period between 1970 and 1986. They focused on the nonagricultural industries and found that only public investment in education is productive, challenging the extent to which other investments, including infrastructure, are productive. They contend that their study is more robust as it corrects for serial correlation and accounts for endogeneity issues (Evans & Karras, 1994).

The conflicting results noted in this literature review signal that the impact of public investment on public infrastructure is susceptible to the inputs analyzed. Depending on the variables analyzed and the method for which they are analyzed, the results can vary from earlier research suggesting large economic gains to the more negligible impacts found in later research.

B. Computable General Equilibrium

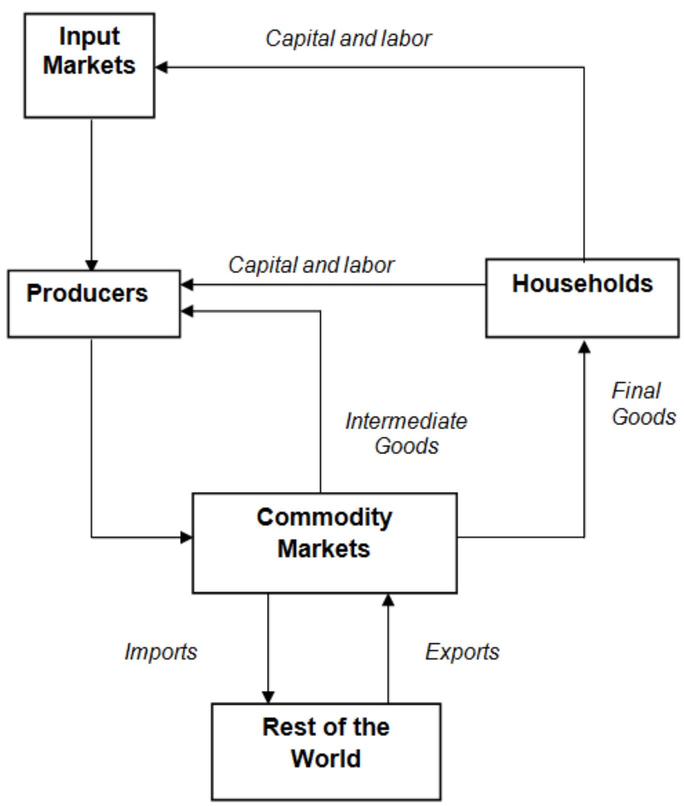
In contrast to empirical analysis, computable general equilibrium (CGE) attempts to replicable the economy in a computer environment based on economic theory. This section provides a general overview of CGE.

Leon Walras, the 19th century economist, provided the fundamental idea behind CGE. His idea stems from the connection among actors and the question of whether supply and demand could simultaneously be equal in all markets. This theoretical question laid the ground for today's "Walrasian" CGE model. In the "Walrasian" model, conditions of constrained optimization and neoclassical production and consumption hold in which producers have profit maximizing motivations, consumers have utility maximizing motivations, though bounded by budget constraints, and price adjustments continue until demand and supply equate (Shoven & Whalley, 1992; Vargas, Schreiner, Tembo, & Marcouiller, 1999; Sue Wing, 2004; Burfisher, 2011).

CGE's three conditions of constrained optimization and neoclassical production and consumption are market clearance, zero profit, and income balance. In the first condition of market clearance, producers' output are determined by households and other firms in the market who consume their products. Additionally, households' are fully employed by the producing firms, thus their spending level is dependent on their employment. This creates a condition in which the quantity of a given commodity must equal the amount demanded. The quantities demanded must also equate to the household endowment such that consumers exhaust their income. The second condition of zero profit requires that prices for a given commodity not equate to more than the cost of creating it. Thus, the price is set by the cost of all inputs and primary factor payments, such as the cost of labor. The final condition of income balance is reflected through households being fully employed by firms and their utility maximizing motivations as consumers. In essence, the producers provide endowments to households which are then fully spent on commodity purchases, taxes, and savings (Sue Wing, 2004).

These conditions represent an economy-wide model and show the link between producers and consumers. Households are provided with income for labor services to producing firms. In turn, they, along with other firms and the government, spend their income on goods, services, taxes, and savings. Meanwhile, their consumption level sets demand for the goods and services which are then translated to the producers. Ultimately, CGE describes a circular flow of income and spending. Equilibrium is reached when the supply and demand set a balanced price in the economy so that all actors are satisfied with the levels of output, input, capital, and savings (Sue Wing, 2004; Burfisher, 2011).

Figure 1: Circular Flow of CGE Models



1. **Social Accounting Matrix**

Because of the Walrasian balancing principles, economic transaction data are carefully aggregated by industry groups, household groups, and government groups in CGE models. Additionally, goods and services are categorized into their respective commodities. It is up to the discretion of the modeler how to categorize the economic transactions, goods, and services (Burfisher, 2011). The transaction values serve as a reflection of the national accounting system, depicting major macroeconomic balances or a benchmark equilibrium (Sue Wing, 2004). A common way to organize these values is with a Social Accounting Matrix (SAM).

A SAM is square matrix detailing the flows between industries, factor of production, households, the government, and outside interest (i.e., imports and exports). The columns show spending/expenditures and the rows show income/receipts. An individual cell within a SAM reflects the double-entry accounting system in which a single transaction is an expenditure through its column account and an income through its row account (Vargas, Schreiner, Tembo, & Marcouiller, 1999; Sue Wing, 2004; Burfisher, 2011). This arrangement identifies all values of production and income which must be balanced by others' expenditures (Sue Wing, 2004).

2. **Static and Dynamic Models**

CGE models can either be static or dynamic. Static CGE models are used to describe more immediate impacts of economic shocks. They assume that the factors are in fixed supply, thus a change in factor supply can result in an economic shock. Static models are useful for before- and after- comparison. However, one of the drawbacks of static models is the inability to show the transition process that occurred because of an economic shock. For example, there may be a period of unemployment or dislocation while industries adjust to a large-scale economic activity. However, the static model will not describe this adjustment period before reaching a new equilibrium.

On the other hand, dynamic models are more useful in describing this adjustment period as it details long-term changes due to an economic shock. Dynamic models trace the timeline in which a shock is introduced to analyze long-term changes. In order to capture these changes, dynamic models are more data intensive, requiring data for consecutive time periods (Burfisher, 2011). Additionally, dynamic models assume the economy has a balanced path of growth throughout the period analyzed (Partridge and Rickman, 1998).

3. **Criticisms of Computable General Equilibrium**

CGE models are subject to a variety of criticisms. Among popular criticisms are those related to general modeling challenges and the subjectivity of CGE modeling. With regards to modeling, CGE models have the same drawbacks as most other economic models. CGE models are both time and data intensive. It is a large undertaking to build a system of equations that underlies the model (Partridge & Rickman, 1998; Wang & Charles, 2010). Additionally, data on output, consumption, expenditure, trade flow, taxes, etc. are needed to construct the model. While national data are readily available, they are more difficult to obtain at subnational levels (Partridge & Rickman, 1998). Even with a standard set of data, CGE models are considered "black boxes" because modelers have the discretion to set parameters, equations, and methods as they wish. Thus, it is difficult for others to meaningfully interpret the results (Sue Wing, 2004; Wang & Charles, 2010; Burfisher, 2011).

Because CGE requires the modelers to specify input parameters that are difficult to obtain, e.g. elasticity values, they often have to make assumptions. One of the key disadvantages with this is that CGE models are not statistical measures and rather open to interpretation. Additionally, if there is conflicting empirical evidence or, simply, if the modelers' assumptions are incorrect, then not only are the parameter values subject to greater challenges, but so are the results (Shoven & Whalley, 1992; Gillig & McCarl, n.d.; and Sue Wing, 2004). Another assumption that CGE modelers make is the choice of a benchmark year. This requires care so that an abnormal condition or economic structure is not the basis of comparison. If particular industries are the focus of the model, then modelers will have to conduct background research to ensure that the industries did not experience any irregular economic events (Partridge & Rickman, 1998).

Another criticism rests on the use of Cobb-Douglas and constant elasticity of substitution (CES) functional forms. These functional forms, while necessary to make the model "computable," are seen as imposing restrictions, including unitary elasticities of substitution, on the economy that may appear arbitrary (Morrison & Schwartz, 1996; Partridge & Rickman 1998; Teruel & Kuroda, 2005).

C. <u>Productivity Gains and Computable General Equilibrium</u>

As the previous section mentioned, there are drawbacks with the use of CGE models. Despite this, some researchers continue to use CGE models to analyze the economic impact of infrastructure investment. Simulating a capital investment through introducing a single equation to models provides CGE modelers with an easy way to compare the impacts of varying capital investments. Additionally, CGE models allow for the simulation of productivity and analysis of price changes unavailable in other popular methods to evaluate transportation investment.

CGE models can simulate productivity changes through various means. Cutler & Davies (2010) provide an overview of three common methods to simulate productivity gains. The Hicks neutral technical change affects the productivity of all factors of production in a given industry in an equally proportional manner. The factor change also impacts the factor endowment, which "takes into account both the quantity and the efficiency of a factor" (Burfisher, 2011). The Harrod neutral effect illustrates a change in labor productivity, while the Solow technical change illustrates a change in capital productivity (Cutler & Davies, 2010). The Hicks neutral technical change and Harrod neutral change are the more popular methods to simulate productivity gains.

By definition, TFP is the residual of the output not explained by the amount of production inputs. Therefore, TFP represents the efficiency of the inputs in the production process (Comin, 2008). CGE modelers often use the Hicks neutral technical change to simulate the introduction of new technology or general efficiency gains. For example, Kawakami, Tiwari, & Doi (2004) analyzed productivity improvement in Japan with the introduction of Intelligent Transportation Systems, while Masayuki, Itoh, & Tiwari (2006) and Hyytiä (2010) used TFP change to simulate efficiency improvements introduced to ports and transportation industry, respectively.

Different simulations are often employed in CGE models to compare outcomes. In the simulations conducted by Cutler and Davies (2010), they analyzed the economic impact on the Ft. Collins, Colorado given a 3% increase using the Hicks neutral technical, Harrod neutral, and Solow technical changes for the manufacturing, computer manufacturing, retail and high services sectors. Their results suggest that a 3% increase in TFP resulted in the greatest economic activity (Cutler & Davies, 2010). Kawakami, Tiwari, & Doi (2004) use both a 20% increase in the TFP and labor factor and found that the latter, Harrod neutral change, results in greater loss in imports, labor, and capital, but greater gains in exports, domestic supply, and domestic consumption than the Hicks neutral technical change. For changes in sectoral prices, both simulations show declines in domestic prices, average output prices, price of composite good, domestic price of export, and domestic price of import. However, the Hicks neutral technical change reflects a smaller decline (Kawakami, Tiwari, & Doi, 2004). Hyytiä (2010) in her analysis of the impacts of infrastructure improvements on the agriculture and food industries in the Finnish region of South Ostrobothnia used both a 10% change in TFP in the transportation sectors and a 10% decrease in transportation costs for all sectors. Her results indicate that under the Hicks neutral technical change simulation, the region's GDP will grow by 1.51% compared to 0.26% growth under the cost reduction simulation. She also found that the food and agricultural industries benefit from the cost reduction, while the other industries benefit from the increase in TFP (Hyytiä, 2010).

D. Implications of this Study

This study attempts to build on the previous research described above to provide a different method to analyze the impacts of shifts in transportation modes. The popular approach of changing TFP is compared to a reduction in labor and capital factors. This researcher has not come across CGE studies describing a *decrease* in labor and capital usage for freight transportation activities. The outcomes of this simulation provide the perspective of what happens when an reduced congestion resulting from the mode shift improves travel time, but price savings are not directly passed on to consumers. Rather, trucking firms, as profit-maximizing institutions who no longer require the same number of laborers to meet their demand, reduce their workforces. Meanwhile, travel time improvements provide these firms with additional cost savings through a decrease in gasoline consumption and trucks, maintenance, etc. Also, mode shift to rail will reduce overall demand for trucking.

III. Analysis

A. Analysis Tools and Data

CGE modeling requires a variety of resources. This section describes the resources used in order to perform the analysis on the Chicago economy. First, data on the transactions that occur within an economy are needed. A possible source, and the one used in this project, of such transaction data are described. The discussion concludes with a description of the modeling system used to compute the mathematical equations for C-CGE.

1. Impact Analysis for PLANning (IMPLAN)

A CGE model includes economic transaction values for industries, households, and the government. As mentioned earlier, such transaction values are often organized into a SAM. The C-CGE model employs a SAM using data from IMpact analysis for PLANning (IMPLAN) software released by MIG Inc. MIG offers such data sets for various geographic levels, including zip code, county, and state (Olson, 2011).

Local economic data in IMPLAN's 1997 database were used to develop the SAM in this analysis. The data include information on industry output, employment, value added, and final demands. Data on industry output stem from a variety of sources, including the Census Bureau's Economic Census, the Bureau of Economic Analysis' (BEA) output estimates, and the Bureau of Labor Statistics' (BLS) employment projections. Employment data are derived from BLS and BEA sources and provide the number of jobs for each industry. Value added information is categorized into employment compensation, proprietary income, other property type income, and indirect business taxes. These data also originate from BLS and BEA. Final demand describes the goods and services, including exports, end users purchase and such information are aggregated from BEA, federal procurement and sales data, and government surveys. While the underlying data comes from a variety of public resources, the compilation methods and estimations are proprietary information (MIG, Inc., 2009).

2. General Algebraic Modeling System (GAMS)

CGE models use high-level modeling systems to find solutions to its system of equations. The C-CGE model uses the General Algebraic Modeling System (GAMS), an algebraic modeling system designed to solve linear equations, nonlinear equations, and mixed integer optimization problems. GAMS is designed to solve a model's statements, which are written in algebraic form. The system allows users to model different values of an element and produce appropriate solution reports, providing ease of sensitivity analysis (GAMS Development Corporation, 2012a). This project uses the most current version of GAMS available, 23.8.2.

GAMS has an array of solvers to find solutions to its system in order to model optimal solution. The original C-CGE model designed by vom Hofe and Kawamura (2006) was written for the use of the MINOS solver, which is designed to solve linear and nonlinear problems. This solver iteratively runs problems in order to come to a final optimal solution. This size of the simulations to increase the TFP by 20% and decrease labor and capital usage by 20% restricts MINOS from computing a feasible optimal solution. Thus, CONOPT, developed by ARKI Consulting and Development in Denmark, was used instead. CONOPT solves nonlinear problems and is a complement to MINOS. For example, if the model or simulation includes a large number of variables or constraints, then CONOPT is a better option than MINOS (GAMS Development Corporation, 2012b).

3. Chicago Computable General Equilibrium (C-CGE) Model

The C-CGE model was developed by vom Hofe and Kawamura. The model is static and replicates the status quo of the economy, a baseline measure to compare to any impacts of exogenous effects. The C-CGE model includes over 900 equations to model the interactions of producers and consumers. The model reaches equilibrium through assumptions that allow for commodity and factor markets to clear. Embedded in C-CGE are equations to check market balance, where composite supply equate to intermediate use, household and government consumption, and public, private, and inventory investment. Factor market equilibrium equations also are included in the model to ensure that demand for factor *f* equals the supply of factor *f*. The model also includes equations to check the equilibrium of foreign and domestic trade balances.

The final outcomes of C-CGE are the calculations of real gross regional product (RGRP), value-added gross regional product (GDPVA), investment, and savings. One of the market clearance criteria set forth in the C-CGE model is that RGRP and GDPVA must be equal and investment and savings must also be equal (vom Hofe & Kawamura, 2006). Refer to vom Hofe and Kawamura (2006) for a detailed description of the C-CGE model.

As described earlier in the discussion of CGE models, a SAM serves a strong organizational purpose in the calibration of data. In C-CGE, the SAM, referred to as the Chicago SAM, is derived from the 1997 version of IMPLAN by MIG, Inc. vom Hofe and Kawamura organized the Chicago SAM into a standard neoclassical CGE equation system and also reduced the number of economic transactions for the analysis (vom Hofe & Kawamura, 2006).

Along with the 25 industries, listed in Table I, the Chicago SAM also includes three value-added sub-accounts (employed labor, self-employed labor and capital), seven household groups by income groups ($0-10,000, $10,000-20,000, $20,000-30,000, $30,000-40,000, $40,000-50,000, $50,000-60,000, and $70,000 and more), two governments (federal and state/local), three investment sectors (public, private, and inventory investment), one enterprise or business savings account, and two trading partners (domestic and foreign). The SAM includes a "make" table which identifies the various commodities that each industry produces. The "use" table details the industries' intermediate demand for commodities (vom Hofe & Kawamura, 2006). The columns account for expenditures, while the rows account for income. Figure 1 below outlines the Chicago SAM configuration.

Because of the initial objective for its development, the Chicago SAM uses a detailed delineation of the transportation industry. Seven transportation related sectors are identified in the Chicago SAM: air transportation, freight transportation, in-house transportation, miscellaneous transportation services (i.e., passenger transit, pipelines, transportation services, and airports/ports), rail transportation, transportation equipment, and water transportation (vom Hofe & Kawamura, 2006). The inclusion of in-house trucking as a separate sector is a unique feature of C-CGE. Recognizing the importance of the in-house trucking, in 1999, the Bureau of Transportation Statistics and the Bureau of Economic Analysis developed the Transportation Satellite Account (Bureau of Transportation Statistics, 1999) that delineated the in-house trucking sector. Since Satellite Account was developed at the national scale, vom Hofe and Kawamura developed similar data set for the Chicago region based on a truck operator survey conducted by the U.S. Department of Transportation, Vehicle Inventory and Use Survey. For a detailed description of the methodology, see vom Hofe and Kawamura (2006).

Table I. 25 Industries in Chicago SAM

Air Transportation	Food	In-House Trucking	Personal Service	Textile
Chemical	Freight	Light Manufacturing	Producer	Transportation Equipment
Construction	Government	Lumber	Rail	Utilities
Extraction	Health	Miscellaneous Transportation	Retail	Water Transportation
FIRE	Heavy Manufacturing	Paper	Steel	Wholesale

B. Analysis Framework

1. Infrastructure Investment

The trucking industry includes many input variables. According to the ATA Information Services, salaries, wages, and fringe benefits made up nearly half of commercial vehicle operating expenses in 1997. This was followed by equipment rentals and purchasing and operating supplies and expenses, each accounting for roughly 20% of operating expenses. The remaining categories included depreciation and amortization (approximately 5%), taxes and

Figure 2: Outline of the Chicago SAM

Expenditures

	Industries	**Commodities**	**Factors of Production**	**Institutions**	**Gov't**	**Trade**	**TOTAL RECEIPTS**
Industries		Make					**Industry Income**
Commodities	Use			Consumption	Consumption	Exports	**Commodity Income**
Factors of Production	Value-Added						**Factors Income**
Institutions			Factors Distribution	Transfers	Transfers	Exports	**Institutional Income**
Gov't	Indirect Business Tax		Factors Taxes		Intergov't Transfers		**Gov't Income**
Trade		Commodity Imports	Factors Imports	Imports	Imports		**Total Imports**
TOTALS	**Industry Outlay**	**Commodity Outlays**	**Factors Outlays**	**Institutional Outlay**	**Gov't Outlays**	**Total Exports**	

Incomes

Source: Adapted from vom Hofe, R., & Kawamura, K. (2006), "Technical Description of the Chicago CGE Model," Chicago: Urban Transportation Center.

licenses (approximately 3%), insurance (approximately 3%), and miscellaneous expenses (approximately 2%) (PBS&J, 2001). Interviews with motor carrier experts in 2003 found that the leading challenges affecting trucking productivity include "rising insurance costs, changes to the hours of service rule, and fuel price volatility" (ICF Consulting, 2003).

The sheer number of these variables and the relationships among them makes it difficult to discern an appropriate percentage change to simulate for either TFP or labor and capital change.

Therefore, a simplistic notion of proportionality is used for the research's simulations. In the first simulation if sizable public investment causes a 20% improvement in travel time for truckers, then all factors of productivity for the trucking sectors would increase at the same rate.

Similarly, a 20% reduction in travel time will reduce the number of hours truckers drive, thus requiring less labor costs for trucking firms. This travel time reduction also carries over to capital costs as less gasoline, trucks, maintenance of trucks, etc., are needed. Continuing with the simple notion of proportionality the 20% reduction in labor will also mean a 20% reduction in capital. Admittedly, there are flaws with these assumptions. For example, labor costs may not be reduced due to union collective bargaining agreements. Or, operating costs, particularly gasoline, fluctuate greatly so that travel time reduction may not actually spur initial cost savings.

2. Organization of SAM12

To utilize the C-CGE model, a SAM was reorganized. A modified categorization was employed in this project to reduce the economic transactions from 25 to 12. The level of sectoral detail for the transportation industry in the Chicago SAM is removed in order to provide a broader analysis of the economic impact of freight investment. The SAM created for this project, SAM 12, includes the following industries: agriculture, construction, manufacturing, heavy manufacturing, transportation/warehousing, miscellaneous transportation, in-house transportation, communication, wholesale, retail, finance/insurance/real estate (FIRE), and services. Refer to Appendices A-I for details on the individual tables that encompass SAM 12.

3. Base Model

The base simulation is the benchmark for which other simulations are compared. Using SAM 12 in C-CGE provides the benchmark condition of the 1997 Chicago economy. The economic conditions that C-CGE computes include RGRP, GRPVA, investment, and savings. As previously mentioned, RGRP and GRPVA must be equal in order to meet an equilibrium condition set by the C-CGE model. This condition also applies to investment and savings.

Table II below provides the economic conditions using SAM 12 in the C-CGE model. The RGRP and GRPVA are nearly $300 billion and investment and savings are nearly $34 billion.

Table II. Chicago's Economic Benchmark Figures (2007)

	Amount ($ million)
RGRP/GRPVA	299,617
Investment/Savings	33,892

4. Simulation 1: Total Factor Productivity or Hicks Neutral Technical Change

In the public infrastructure context, relating TFP growth to efficiency implies that public infrastructure increases productivity of private factors (Montolio & Solé-Ollé, 2009). For trucking sector this can occur in many ways including increased capacity of the road network, technological improvements. However, for the context of this study, it is assumed that mode shift from truck to rail can have two effects on the efficiency of trucking sector:1) reduced congestion on roads, and 2) increase in the value of goods transported since the loads that shift to rail are most likely to be less valuable. Following this reasoning, the first simulation employs an increase of 20% in TFP that impacts the entire production function. This method, called the Hicks neutral technical change, is used by many researchers, including Tiwari, Doi, & Itoh (2003), Kawakami, Tiwari, & Doi (2004), Masayuki, Itoh, & Tiwari (2006), Cutler & Davies (2010), and Hyytiä (2010).

To illustrate the simulation in C-CGE, the production function used in the C-CGE model is as follows:

$$XD_a = ad_a \cdot \prod_f FD_{a,f}^{\alpha_{a,f}}$$

where XD_a an industry's activity level or output and $FD_{a,f}$ is factor demand of inputs such as labor and capital. The parameter ad_a represents the industry's technology shift parameter. Thus, a change in ad_a simulates a change in TFP.

In order to simulate a productivity gain from congestion improvements, a 20% increase in TFP was applied only to the in-house trucking and transportation/warehousing sectors. The results from this simulation should reveal positive impacts on RGRP/GRPVA and investment/savings.

5. Simulation 2: Decrease in Labor and Capital

Mode shift may alleviate congestion and also allow trucking firms to focus on high-value goods to improve the efficiency of trucking sector. However, trucking firms are susceptible to an array of capital costs. Thus, efficiency gains, as illustrated by TFP changes, may not accurately depict the entire impacts of mode shift on the trucking sectors. The simulation to decrease capital and labor factor demands suggests that the trucking industry will see a reduction in capital cost (gasoline, trucks, maintenance) and labor (fewer drivers) because of the greater efficiency. While the reduction in labor and capital are seen as cost savings to the transportation sector, they do impact other industries from which the trucking industries purchase. With less capital to use, the in-house and transportation/warehousing sectors will purchase fewer inputs. The results under this simulation should show decreases in RGRP/GRPVA.

In order to simulate productivity change in labor and capital, Hanson and Rose (1997) used a conversion function in order to generate "efficiency units" from labor hours and capital stock. This created a factor augmentation parameter for each sector. To show an increase in productivity change for labor and capital, they raised the new factor augmentation parameter by a percentage. The same method was followed by Culter and Davies (2010) in their analysis of Ft. Collins, Colorado. The simulation in C-CGE follows these methods. The C-CGE production function includes variables for factor demand. In order to simulate a decrease in labor and capital usage for the in-house trucking and transportation/warehousing sectors, the values for these sectors' factor demands were decreased by 20% prior to the calculation of the production function. The optimal method is to fix the demand for the in-house and trucking/warehousing sectors in order to simulate a scenario following HLB Decision Economics' (2008) findings that trucking demand elasticity with respect to truck delay is nearly inelastic. However, C-CGE does not allow for the demands to remain constant. Thus, the results of the second simulation incorporate changes in demand that may not be realistic.

IV. DISCUSSION

A. <u>Simulation Results</u>

Two types of productivity impacts were simulated in this research. First, a mode shift that reduces congestion and also enable trucks to focus on high-value shipments, was introduced into the economy. This increase in TFP or Hicks neutral technical change was a 20% shift in the production function, which also caused the productivity of capital and labor factors to increase as well. Compared to the base model, this resulted in over a 1% increase in RGRP/GRPVA and nearly a 27% increase in investment/savings. The results suggest that a 20% increase in TFP will cause greater demand for the services that the in-house and transportation/warehousing sectors provide. This increase in service demand increases the need for labor, which then increases employment and household endowments.

The second simulation decreased capital and labor usage by 20%. This was done through a 20% reduction in labor and capital factor demand prior to the calculation of the production function. As mentioned before, the demand for in-house and transportation/warehousing sectors' output could not remain constant in the C-CGE model and may not reflect the more realistic scenario in which trucking demand is not impacted by travel time reduction (HLB Decision Economics, 2008). Compared to the base model, this simulation resulted in roughly one-third of a percent decline in RGRP/GRPVA and approximately 7% decrease in investment/savings. Table III below illustrates the outcomes of the simulation and compares them with the base model.

Table III. Impacts of Total Factor Productivity and Capital and Labor Factor Demand Changes on the Trucking Sectors of Chicago's Economy (1997)

	20% Increase in TFP ($ million)	Change (%)	20% Decrease in Capital and Labor ($ million)	Change (%)
RGRP/GRPVA	302,869	1.09	298,647	(0.32)
Investment/Savings	43,038	26.99	31,527	(6.98)

The results from the simulations suggest that a 20% increase in productivity for truck drivers has a strong impact on Chicago's GRP. Depending on whether congestion improvement is viewed as a change to the productivity of all sectors or whether the impacts are largely confined to capital and labor usage reductions within only the trucking sectors, there is a distinction between whether the impact is positive or negative. The 1.42 percentage point variation between the two simulations suggests that a 20% increase in productivity for trucks may impact GRP between -0.32% and 1.09%. However, the -0.32% change should be interpreted with caution. Sector output was not held constant in the second simulation and actually caused output for in-house trucking and transportation/warehousing to decrease by 1.48% and 3.95%, respectively. If output was held constant for these sectors, the change in GRP would likely be near 0.00.

The changes to investment/savings, especially in the TFP simulation, are larger than those to RGRP/GRPVA. The individual variables that are used in both the investment and savings equations were investigated. The investment equation showed no sensitivity to changes in TFP or capital and labor factor demand. However, savings, particularly state and local government savings, is very responsive to both changes. A 20% TFP change for the in-house trucking and transportation/warehousing sectors causes state and local government savings to increase by approximately $11.4 billion. Meanwhile, a 20% reduction in labor and capital factors decreases state and local government savings by roughly $2.7 billion. Table IV compares how TFP and capital and labor changes affect the individual savings variables. The simulations' impact on state and local government savings suggests a relationship may exist between it and productivity that may warrant further exploration in a separate research.

Table IV. Comparison of Simulation 1 and Simulation 2 with the Chicago's Benchmark Savings Variables

Variable ($ million)	Base	Simulation 1	Difference between Simulation 1 and Base	Simulation 2	Difference between Simulation 2 and Base
Total depreciation expenditure	30,907	30,934	27	30,689	(218)
Total industry savings	10,362	10,415	53	10,344	(18)
Total household savings	13,610	12,871	(739)	13,790	180
Federal government savings	28,635	27,882	(753)	28,790	155
State and local government savings	(971)	10,446	11,416	(3,633)	(2,662)
Enterprise savings	1,180	(792)	(1,972)	1,637	457
Factor savings	(19,001)	(19,243)	(243)	(18,942)	59
Domestic savings	(30,970)	(29,614)	1,356	(31,288)	(318)

Aside from aggregate economic indicators, the C-CGE model provides estimations for industry and commodity prices. Table V compares prices under both simulations with prices under the benchmark economy. Under the first simulation, in which TFP is increased by 20%, the average transaction price between in-house trucking and other sectors decreased by 13.30%. The average output price for the in-house trucking sector also decreased by 13.30%. The average transaction price between transportation/warehousing and other sectors decreased by 9.50% and the average output price for the transportation/warehousing sector decreased by 10.00%. These results suggest that a 20% increase in TFP is creating greater efficiencies that lower the in-house trucking and transportation/warehousing sectors cost to provide services. Moreover, firms in these sectors are passing these cost-savings along to consumers. However, under the second simulation, prices increase. Prices increase in order to account for a 20% reduction in labor and capital inputs. The average transaction price between in-house trucking and other sectors and transportation/warehousing and other sectors increase by 3.80% and 3.10%, respectively. Similar to the first simulation, the cost increases are passed on to consumers. The average commodity price for in-house trucking increases by 3.80% and for the transportation/warehousing sector the average commodity price increases by 3.30%.

Table V. Percent (%) Change of Prices Compared to the Base Simulation

	Average Industry Transaction Price		**Average Commodity Price**	
Activity/Commodity	**Simulation 1**	**Simulation 2**	**Simulation 1**	**Simulation 2**
Agriculture	(1.00)	0.30	(1.00)	0.30
Heavy Manufacturing	0.80	(0.20)	0.80	(0.20)
In-House Trucking	(13.30)	3.80	(13.30)	3.80
Retail	(0.20)	0.10	(0.20)	0.10
Construction	(0.40)	0.10	(0.40)	0.10
Transportation/Warehousing	(9.50)	3.10	(10.00)	3.30
Communication	0.00	0.00	0.00	0.00
FIRE	(0.20)	0.00	(0.20)	0.00
Manufacturing	0.30	(0.10)	0.30	(0.10)
Miscellaneous Transportation	0.20	0.00	0.50	(0.10)
Wholesale	0.80	(0.20)	0.80	(0.20)
Service	0.10	0.00	0.10	0.00

The results of the simulation provide support to the hypothesis that a positive productivity change will positively influence the aggregate economy and vice versa. Additionally, the results provide figures to compare the estimated cost of a 20% gain in efficiency improvement with the economic benefit. Using the RGRP/GRPVA calculated in the first simulation, approximately $3.3 billion in overall economic benefit is derived from this analysis. Overall, the simulations indicate that TFP change has a greater positive impact on the aggregate economy as well as consumers, while the potential reduction in the factor inputs to the trucking as a result of the mode shift and subsequent improvement in the efficiency negatively impacts the economy and consumers. As noted before, the latter simulation likely overstated the negative economic impacts because of the inability to hold sector output constant.

B. Comparison to Chicago SAM

The simulations were also performed using the original Chicago SAM in order to compare how the aggregation schemes affect the economic indicators. The Chicago SAM includes 25 sectors, six of which are related to transportation. The benefit of the Chicago SAM categorization is that productivity and factor usage changes can be made to sectors that are directly use roads. The Chicago SAM categorizes the freight sector independently, whereas the SAM 12 groups freight, rail, and water as one category under transportation/warehousing. In-house trucking is independently listed in both SAMs (vom Hofe & Kawamura, 2006). The separation of the freight sector in the Chicago SAM allows for greater precision in the analysis, which means that the changes under both simulations to increase TFP and decrease labor and capital usage will be smaller compared to the use of SAM 12.

Tables VI and VII compare resulting RGRP/GRPVA and investment/savings figures for SAM 12 and the Chicago SAM with the base model. The results confirm that the Chicago SAM's detailed delineation of the transportation sectors leads to smaller changes in the economic indicators. Under the first simulation, which increases TFP by 20% in the trucking sectors, the use of the Chicago SAM resulted in a 0.76% increase in RGRP/GRPVA and 16.78% increase in investment and savings over the base model. The difference between RGRP/GRPVA using SAM 12 and the Chicago SAM is $970 million and difference between investment/savings is $3.46 billion. Under the second simulation, which decreases the trucking sectors' capital and labor inputs by 20%, the difference in RGRP/GRPVA is $347 million and investment/savings is $955 million.

While the impacts on aggregate economic indicators are smaller when C-CGE uses the Chicago SAM, the advantage of using CGE is the ability to determine price changes. Table VIII lists the transaction price between industries and the commodity prices for each of Chicago SAM's 25 sectors. Using SAM 12, the first simulation resulted in an average industry-to-industry transaction price decrease of 13.30% for the in-house trucking sector. The transportation/warehousing sector's price decreased by 9.50%. The average commodity price for each respective sector decreased by 13.30% and 10.00%. Using the Chicago SAM, the average industry transaction price decreased by 13.60% for the in-house trucking sector and decreased by 10.00% for the freight sector compare to the base scenario. The average commodity price for in-house trucking reduced by 13.60% and for freight reduced by 10.70%. As with SAM 12, C-CGE assumes that the cost-savings accrued by the trucking sectors are passed on to consumers. The ability to increase TFP in sectors that are directly impacted by trucking induces larger price changes for the affected sectors.

Table VI. Comparison of SAM 12 and Chicago SAM ($ millions)

		SAM 12		***Chicago SAM***	
	Base	**Simulation 1**	**Simulation 2**	**Simulation 1**	**Simulation 2**
RGRP/GRPVA	299,617	302,869	298,647	301,899	298,994
Investment and Savings	33,892	43,038	31,527	39,579	32,482

Table VII. Comparison of SAM 12 and Chicago SAM Percent (%) Change

	SAM 12		***Chicago SAM***	
	Simulation 1	**Simulation 2**	**Simulation 1**	**Simulation 2**
RGRP/GRPVA	1.09	(0.32)	0.76	(0.21)
Investment and Savings	26.99	(6.98)	16.78	(4.16)

The second simulation also reflects changes in prices. Using the Chicago SAM, both the average industry transaction price and average commodity price for the in-house trucking sector increased by one-tenth of a percentage point. The average industry transaction price change for the transportation/warehousing sector was 3.10% compare to 2.90% for the freight sector using the Chicago SAM. The average commodity price change for the transportation/warehousing sector was a 3.30% increase using SAM 12 and for the freight sector using the Chicago SAM was a 3.10% increase. As with the simulation using SAM 12, the production costs for the trucking sectors increased due to lost of capital and labor inputs. The firms are then supplementing the higher production cost by charging consumers higher prices.

The comparison of the trucking sectors' industry transaction price and commodity price changes using SAM 12 and the Chicago SAM exhibit similar results. The price changes using the Chicago SAM are smaller due to the detailed categorization of all sectors. Future research can examine how price changes in C-CGE differ between the use of SAM 12 and Chicago SAM.

Table VIII. Comparison of Price Change (%) from Base Simulation

	Average Industry Transaction Price		Average Commodity Price	
Activity/Commodity	**Simulation 1**	**Simulation 2**	**Simulation 1**	**Simulation 2**
Extraction	(1.10)	0.30	(1.10)	0.30
Lumber	0.60	(0.10)	0.60	(0.10)
Heavy Manufacturing	1.10	(0.30)	1.20	(0.30)
Freight	(10.00)	2.90	(10.70)	3.10
In-House Trucking	(13.60)	3.90	(13.60)	3.90
FIRE	0.00	0.00	0.00	0.00
Government	0.50	(0.10)	0.50	(0.10)
Construction	(0.60)	0.20	(0.60)	0.20
Paper	0.00	0.00	0.00	0.00
Light Manufacturing	0.60	(0.10)	0.60	(0.10)
Water Transportation	0.20	(0.10)	0.20	(0.10)
Utilities	0.10	0.00	0.10	0.00
Personal Service	(0.30)	0.10	(0.30)	0.10
Food	(0.20)	0.00	(0.20)	0.00
Chemical	0.10	0.00	0.10	0.00
Transportation Equipment	0.30	(0.10)	0.30	(0.10)
Air Transportation	0.10	0.00	0.10	0.00
Wholesale	0.60	(0.10)	0.60	(0.10)
Producer	0.20	(0.10)	0.20	(0.10)
Textile	(0.20)	0.10	(0.20)	0.10
Steel	0.10	0.00	0.10	0.00
Rail	0.50	(0.10)	0.50	(0.10)
Miscellaneous Transportation	0.20	(0.10)	0.80	(0.20)
Retail	(0.10)	0.00	(0.10)	0.00
Health	0.00	0.00	0.00	0.00

C. Sensitivity Analysis

In order to analyze the effects of the varying magnitudes of changes in TFP and capital and labor factor inputs, different percentages were used for both scenarios. Table IX lists in 5% increments the change from the base scenario through a 35% increase in TFP change. The changes to both RGRP/GRPVA and investment/savings gradually become smaller with the larger TFP change. This follows the notion that initial productivity gains are more impactful. Larger TFP increases are not realistic for a long-term analysis of a large scale transportation investment. As the sensitivity analysis shows, benefits will ultimately level off. Because the use of TFP in C-CGE impacts the production function, a low to moderate change in TFP may more accurately represent real-world impacts of a truck to rail mode shift.

Table IX. Sensitivity Analysis for TFP Change

	Base	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**	**35%**
RGRP/ GRPVA ($ millions)	299,617	300,519	301,356	302,137	302,869	303,560	304,215	304,840
Change (%)		0.30	0.28	0.26	0.24	0.23	0.22	0.21
Investment/ Savings ($ millions)	33,892	36,181	38,458	40,738	43,038	45,371	47,752	50,192
Change (%)		6.75	6.29	5.93	5.65	5.42	5.25	5.11

The sensitivity analysis for capital and labor factor demand change also used an incremental change of 5%. A 5% decrease in capital and labor factor demand through a 35% decrease in the trucking sectors was simulated. Table X shows that RGRP/GRPVA and investment and savings gradually decline as capital and labor factor demand changes are larger. Because of the multitude of variables included in the trucking sector's capital inputs, larger capital and labor factor demand changes may not accurately represent alterations the trucking sector may experience because of mode shift. For example, the volatility of fuel prices or extreme weather conditions can easily offset or reduce capital cost. A more moderate percent change such as 15-20% may be better suited for analysis of a large scale transportation investment.

Table X. Sensitivity Analysis for Capital and Labor Factor Demand Change

	Base	(5%)	(10%)	(15%)	(20%)	(25%)	(30%)	(35%)
RGRP/ GRPVA ($ millions)	299,617	299,397	299,163	298,914	298,647	298,361	298,053	297,718
Change (%)		(0.07)	(0.08)	(0.08)	(0.09)	(0.10)	(0.10)	(0.11)
Investment/ Savings ($ millions)	33,892	33,341	32,765	32,161	31,527	30,857	30,146	29,390
Change (%)		(1.63)	(1.73)	(1.84)	(1.97)	(2.13)	(2.30)	(2.51)

V. CONCLUSIONS

Using data for the Chicago region, a mode shift that improves efficiency for the transportation sector has an impact of between -0.32 to 1.09% change in RGRP/GRPVA, representing the effect of reduced factor inputs and improved operational efficiency, respectively. The lower bound of this range assumes that labor and capital usage will decline as the transportation sector will require less labor and capital input cost from efficiency gains. The upper bound assumes a technological change has shifted the production of all factor inputs in the transportation sectors. Compare to HLB Decision Economics' (2008) research which found that trucking demand is almost perfectly inelastic with respect to delay, the lower bound may overestimate the negative economic changes. Overall, the findings from this research provide additional support to research that found public infrastructure investment as having a positive economic benefit.

Unlike previous research, though, this research implies that mode shift can generate considerable positive economic impact if it improves TFP. The means to achieve the mode shift, or the improvement in the efficiency for that matter, was not examined in this study, and is an area to be studies further. This research can improve with consideration that such mode shift may require fairly substantial government intervention which may involve government borrowing in order to finance the project. Policy interventions, which may not require expensive projects may result in market distortions. Another issue to be examined further is a broad impact of truck-to-rail mode shift. For example, an increase in rail freight will encourage the building of large intermodal centers, which can have a significant impacts on the local and regional economy.

While this study provides a different perspective in evaluating the potential impacts of mode shift, it is not without flaws. Aside from the drawbacks of CGE as described earlier, attempting to evaluate productivity change using CGE alone may be insufficient. Productivity changes have long-term implications. In addition, the spatial distribution of the impacts should be a rich area of further research.

The valuation of productivity is a great weakness in this study. The inability to capture the appropriate level to change TFP, labor, and capital led to rather simple approach that assumed the magnitudes of the changes. A stronger estimation of productivity changes will provide a richer analysis, but to identify the individual variables that affect these production factors is technically challenging. However, even without a sophisticated productivity valuation, the results from the simulations indicate that state and local government savings is sensitive to productivity changes. This area could be explored further.

Other areas of future exploration involve the C-CGE model. Model closure concerns prevented sector output from being held constant. In order to replicate a more realistic scenario, the second simulation require demand to remain constant. Resolving this model closure concern could provide an interesting analysis of resulting economic indicators and price changes. If this concern is resolved, then the questions raised in this research can be explored using the Chicago SAM. Questions regarding the price changes between SAM 12 and the Chicago SAM would be more thoroughly addressed as well.

Results from the simulations provide support to the hypothesis that a positive productivity change will positively influence the aggregate economy and vice versa. Overall, the simulations indicate that TFP change has a more positive impact on the aggregate economy and lowers the industry-to-industry transaction and commodity prices. Alternatively, a simultaneous labor and capital change negatively impacts the economy and increases industry transaction and commodity prices. The research does provide a unique perspective with regard to labor and capital factor demand. Their reduction in this study enhances the CGE viewpoint that producers are seeking maximum profits. It may be the case that a reduction in labor and capital usage is a more realistic scenario to evaluate the long-term impact of changes in the freight sector.

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VII. appendices

8.1. Appendix A: Use Table ($ millions)

	Agriculture	Construction	Manufacturing	Heavy Manufacturing	Transportation/ Warehousing	Miscellaneous Transportation	In-House Trucking	Communications	Wholesale	Retail	FIRE	Service
Agriculture	222	292	8,809	35	1	15	-	1,095	22	10	472	324
Construction	46	11	871	186	159	865	25	566	143	107	3,419	912
Manufacturing	86	6,012	34,719	6,827	852	1,434	555	486	1,715	230	563	6,566
Heavy Manufacturing	18	541	1,152	4,096	305	349	23	101	299	90	96	1,248
Transportation/ Warehousing	16	400	2,920	345	1,642	76	45	49	135	29	178	566
Miscellaneous Transportation	2	34	773	195	354	452	5	50	204	44	178	585
In-House Trucking	381	1,622	515	186	-	-	-	33	766	535	47	1,823
Communications	6	128	2,194	387	302	354	155	1,970	939	322	1,125	2,423

Wholesale	26	829	7,138	1,725	287	187	227	106	831	31	131	1,574
Retail	2	814	1,157	115	122	484	-	329	340	38	141	388
FIRE	60	393	2,486	727	425	385	61	356	1,364	962	12,023	6,334
Service	18	2,242	8,605	2,074	958	1,726	610	1,585	5,100	1,642	6,228	20,088

8.2. Appendix B: Value-Added Table ($ millions)

	Agriculture	Construction	Manufacturing	Heavy Manufacturing	Transportation/ Warehousing	Miscellaneous Transportation	In-House Trucking	Communications	Wholesale	Retail	FIRE	Service
Employee Compensation	339	8,768	27,196	9,103	3,174	5,326	2,818	3,683	14,479	7,596	18,729	71,862
Proprietary Income	154	1,583	1,481	590	326	252	389	777	466	566	1,654	9,786
Other Property Income	265	383	15,831	2,577	1,054	586	834	6,157	5,222	2,324	39,736	9,760

8.3. Appendix B: Value-Added Table ($ millions)

	Agriculture	Construction	Manufacturing	Heavy Manufacturing	Transportation/ Warehousing	Miscellaneous Transportation	In-House Trucking	Communications	Wholesale	Retail	FIRE	Service
Federal Gov't	7	26	215	163	33	71	27	280	974	474	1,452	339
State/Local Gov't	35	126	1,045	791	159	346	133	1,359	4,734	2,301	7,056	1,646

8.4. Appendix C: Indirect Business Tax Table ($ millions)

	Agriculture	Construction	Manufacturing	Heavy Manufacturing	Transportation/ Warehousing	Miscellaneous Transportation	In-House Trucking	Communications	Wholesale	Retail	FIRE	Service
Agriculture	1,632	-	48	-	0	-	-	-	-	-	-	4
Construction	-	24,205	-	-	-	-	-	-	-	-	-	-
Manufacturing	21	-	111,520	921	-	-	-	3	-	64	-	4,580
Heavy Manufacturing	-	-	496	29,527	-	-	-	-	-	18	-	80
Transportation/ Warehousing	-	-	-	-	9,617	-	-	536	-	0	-	-
Miscellaneous Transportation	-	-	1	14	290	11,294	-	870	-	46	340	52
In-House Trucking	-	-	-	-	-	-	5,907	-	-	-	-	-
Communications	-	-	-	-	-	13	-	18,837	-	3	-	128
Wholesale	-	-	-	-	-	-	-	-	37,734	-	-	-
Retail	-	-	-	-	-	-	-	-	-	17,302	-	-
FIRE	-	-	-	-	-	-	-	-	-	-	91,919	1,308

Service	-	-	1	10	1	3	-	737	-	51	50	135,370		

8.5. Appendix D: Indirect Business Tax Table ($ millions)

	Agriculture	Construction	Manufacturing	Heavy Manufacturing	Transportation/ Warehousing	Miscellaneous Transportation	In-House Trucking	Communications	Wholesale	Retail	FIRE	Service
Foreign Imports	427	-	4,433	1,055	-	83	-	2	-	-	4	22
Domestic Imports	9,845	460	29,250	3,316	195	1,187	-	3,854	52	724	7,706	9,427

8.6. Appendix E: Distribution of Factor Income ($ millions)

	Labor	Capital	Property
Households 0-10k	786	45	244
Households 10-20k	4,091	390	1,291
Households 20-30k	10,940	733	2,311
Households 30-40k	16,992	1,318	3,083
Households 40-50k	19,806	1,381	3,449
Households 50-70k	41,509	3,604	5,664
Households 70k+	52,861	9,584	16,061
Federal Gov’t	22,256	968	7,973
State/Local Gov’t	2,724	-	1,995
Enterprises (Corporations)	-	-	-
Capital	139	-	41,270

8.7. Appendix E: Distribution of Factor Trade ($ millions)

	Labor	Capital	Property
Foreign Imports	-	-	303
Domestic Imports	968	-	1,086

8.8. Appendix F: Final Demand by Institutions ($ millions)

	Households 0-10k	Households 10-20k	Households 20-30k	Households 30-40k	Households 40-50k	Households 50-70k	Households 70k+	Federal Gov't	State/Local Gov't	Capital	Inventory
Agriculture	7	10	13	14	14	23	21	(4)	1	0	(0)
Construction	-	-	-	-	-	-	-	39	1,618	15,694	-
Manufacturing	897	1,401	1,786	1,931	1,918	3,325	2,975	454	1,339	4,839	244
Heavy Manufacturing	216	480	706	875	916	1,882	1,728	84	168	6,233	68
Transportation/ Warehousing	70	114	145	174	179	349	391	3	121	339	108
Miscellaneous Transportation	112	171	234	248	229	470	611	11	181	73	15
In-House Trucking	-	-	-	-	-	-	-	-	-	-	-
Communications	486	672	821	902	804	1,410	1,225	54	961	141	1
Wholesale	358	569	781	893	878	1,708	1,510	9	391	4,145	904
Retail	626	1,025	1,556	1,756	1,772	3,654	3,296	34	33	588	(1,048)

FIRE	1,491	2,197	3,028	3,903	3,828	7,159	7,490	21	861	1,196	-
Service	3,603	3,765	5,539	7,416	5,909	12,013	12,726	5,115	15,540	356	(4)

8.9. Appendix G: Inter-Institutions and Inter-Governmental Transfers ($ millions)

	Households 0-10k	Households 10-20k	Households 20-30k	Households 30-40k	Households 40-50k	Households 50-70k	Households 70k+	Federal Gov't	State/ Local Gov't	Enterprises (Corporations)	Capital	Inventory Additions / Deletions
Households 0-10k	3	4	4	7	8	13	22	3,159	274	56	-	-
Households 10-20k	13	19	18	32	39	62	106	5,615	1,532	276	-	-
Households 20-30k	23	33	30	56	68	107	184	3,984	2,308	477	-	-
Households 30-40k	21	31	28	52	64	100	172	2,449	1,905	447	-	-
Households 40-50k	34	51	46	85	103	163	280	1,682	1,374	726	-	-
Households 50-70k	50	74	67	122	149	236	405	1,750	2,099	1,050	-	-
Households 70k+	125	185	168	307	374	590	1,014	1,225	1,369	2,631	-	-
Federal Gov't	55	447	1,793	3,126	3,674	8,362	12,784	-	-	-	-	-

State/Local Gov’t	47	215	469	746	854	1,890	2,346	526	-	-	-	-
Enterprises (Corporations)	-	-	-	-	-	-	-	9,679	(2,836)	-	-	-
Capital	(6,286)	(1,983)	(1,562)	(2,770)	868	728	24,614	28,635	(971)	1,180	-	(687)
Inventory Additions/ Deletions	-	-	-	-	-	-	-	-	-	-	-	-

8.10. Appendix H: Institutional and Governmental Exports ($ millions)

	Foreign	Domestic
Households 0-10k	5.403	-
Households 10-20k	6.094	-
Households 20-30k	7.000	-
Households 30-40k	6.967	-
Households 40-50k	6.057	-
Households 50-70k	9.461	-
Households 70k+	6.836	-
Federal Gov’t	2.332	6.716
State/Local Gov’t	11.193	179.171
Enterprises (Corporations)	-	-
Capital	75.865	-
Inventory Additions/Deletions	35.500	121.964

8.11. Appendix I: Institutional and Governmental Imports ($ millions)

	Households 0-10k	Households 10-20k	Households 20-30k	Households 30-40k	Households 40-50k	Households 50-70k	Households 70k+	Federal Gov't	State/ Local Gov't	Enterprises (Corporations)	Capital	Inventory
Foreign	187	344	532	610	664	1,272	1,424	323	236	-	19,027	85
Domestic	2,491	3,664	5,061	6,186	5,879	11,272	11,176	662	3,227	-	30,620	472

[i] Bureau of Labor Statistics, accessed March 22, 2008.
[ii] The Workforce Boards of Metropolitan Chicago, 2005
[iii] http://www.bls.gov/emp/ep_table_109.htm Accessed April 2012
[iv] Koopman, Robert B., Hugh M. Arce, Edward J. Balistreri, and Alan K. Fox. Large Scale CGE Modeling at the United States International Trade Commission. Office of Economics, U.S. International Trade Commission, Washington, DC 20436. 2002 provides a dated but comprehensive scan of CGE models in the U.S.