APPLICATIONS OF NEW ECONOMIC GEOGRAPHY IN

REGIONAL ECONOMIC ANALYSIS AND FORECASTING

BY

THOMAS COLE TANNER

ABSTRACT

The fundamental goals of this research are fourfold. The first is to lay out an alternative technique for managing and presenting regional economic accounts utilizing aspects of both input-output tables and social accounting matrices. Secondly, to develop and implement an estimation technique that allows estimation of interregional trade flows, necessary for a multi-region model of the economy, without using any trade flow data. Third, to establish a relatively simple set of "New Economic Geography" inspired behavioral equations, which can be used in conjunction with these accounts to drive a multi-region model of the economy. Finally, to explore extensions and improvements of the basic model structure that might be implemented to expand the functionality of the basic model.

INDEX WORDS: Economic Geography, Economic Impact Analysis, Economic Modeling, Regional Economics, Urban Econoimcs, Computable General Equilibrium, Input-Output

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Chapter 1

A Primer on Regional Science and Economic Geography

Introduction

The objective of this paper is to unite several different threads of economic research to develop the framework for a regional computable general and geographic equilibrium model of the United States economy. The model will incorporate several different tools that will be familiar to those that work in the fields of regional and urban economics, and those in other economic fields will have at least a passing familiarity with many of the tools that will be used. Key tools and concepts that will be incorporated into the model will include: input-output analysis, Social Accounting Matrices, gravity modeling, and new economic geography. The model framework that is developed is extremely simple, at least by the standards of most computable general equilibrium models, yet is capable of generating a wide range of extremely complex economic behaviors/outcomes, and can model these behaviors at an extremely fine level of geographic and sectoral detail.

In Chapter 1, we will briefly review the fundamentals of economic geography from the foundation initially developed by von Thünen (1826). Of particular interest is the schism that developed between economics, which evolved as a largely aspatial science ("economics without geography"), and the German regional science tradition evolved models of spatial distribution, largely without foundation in economic principles ("geography without economics"). Chapter 1 will also briefly outline the gulf between regional science, which attempts to analyze observed spatial interaction behavior and has produced a wealth of interesting empirical observations and statistical relationships, but in many respects lacks strong theoretical foundations, and economic geography. The recent and significant development of new economic geography, on the other hand, has begun to demonstrate that economic theories of monopolistic competition and increasing returns to scale can yield a wealth of interesting spatial results. The balance of the paper involves, in essence, an attempt to bring the theoretical rigor of new economic geography to the practical applications of interest to regional science – or perhaps vice-versa.

Chapter 2 develops a data structure and regional economic framework for the model. The data structure will be built upon the traditions of input-output tables and upon the more recently popularized social accounting matrix methodology. Each of these data structures will be explored in depth. The two data structures will then be merged to generate an approach that combines (for our purposes, at least) the best aspects of both techniques. This data structure lends itself to a subtly different way of exploring regional economies and interregional interactions; we will be stripping away a huge amount of "artificial complexity," and defining regional economies in a great deal of detail, but using only a very minimal taxonomy.

In Chapter 3, the model will be populated using United States data from a variety of sources, including County Business Patterns, Bureau of Labor Statistics (BLS) Current Employment and Wages (CEW) data, U.S. Make and Use tables from the BLS and the Bureau of Economic Analysis (BEA), REIS data, and others. While U.S. data is used to build the model, the basic data structures could readily be developed for any geography, and the basic model framework is extremely flexible to data availability and to the level of geography that is of interest.

In chapter 4, we will use the data developed in chapter 3 to estimate a comprehensive set of trade flows for United States counties. The technique we develop for estimating trade flows is based upon a traditional gravity model formulation derived from a Dixit-Stiglitz (constant elasticity of substitution nested Cobb Douglas) production function, but is unique in that it does not rely in any way on existing trade flow data for calibration. Instead, it relies on panel data regarding the location of suppliers and demanders to, as it were, snatch trade flows from the air. The estimation process in this chapter will estimate key parameters necessary to realize an applied economic geography model: elasticities of substitution and transportation costs.

In chapter 5, we will provide background on the fundamentals and key theoretical results of new economic geography, particularly as it pertains to economic forces of geographic agglomeration and dispersion. We will examine the key characteristics of our new economic geography model using a very simple two region economy that offers only a manufacturing commodity and land. The model will allow us to see the forces that act to encourage economic agglomeration, the forces that act to encourage dispersion of economic activity, and the resulting economic-geographic equilibria that can result from such a model.

In chapter 6, the basic model and fundamental forces will be extended to flesh out a set of behavioral functions that will govern the agents that were defined in chapters 2 and 3. The new economic geography model will be used to drive a model of economic behavior consistent with the trade flows calculated in chapter 4, and will be used to estimate the dynamics movement of suppliers and demanders across all counties in the US over time. The model we develop will be distinctive in that it allows for any number of industries, all of which are characterized by monopolistic competition and all of which may exhibit joint production characteristics. The model is also distinct in that transportation is explicit, as opposed to relying upon the usual iceberg transportation costs assumption. All production "factors" (in quotes for reasons that will become apparent) are fully mobile, except land. The tension between land prices and transportation costs will drive the geographic equilibrium in the model. We will use the data developed in chapters 2, 3, and 4 to produce a relatively simple, yet powerful multi-region, multiyear county level computable general economic and geographic equilibrium model of the United States.

Chapter 7 will lay out opportunities for developing further modeling capabilities within the broad framework already laid out. Opportunities for model expansion that will be explored include: adding the capability to endogenously estimate the appearance or disappearance of new industries in a region, the addition of a demographic forecast to the model, the expansion to a multinational model, and the addition of greater labor market detail to the core model structure. Finally, chapter 7 will offer concluding remarks regarding the research conducted to date, and how it fits into the broader literature.

The Origins of Economic Geography

Geography matters. Nevertheless, examination of the vast majority of economic research makes it clear that questions regarding the location of economic activity are, by and large, ignored. Even when questions of the spatial distribution of economic activity are acknowledged, the underlying forces driving the geographic distribution of economic activity is seldom addressed; rather, the spatial issue is taken as given, and the researcher moves on from there.

The foundations of economic geography can be traced to the work of von Thünen (1826). Von Thünen describes an isolated city and its relationship to the surrounding farms. These farms produce a variety of crops, differing both in terms of yield and in terms of transportation costs. For this city, von Thünen explored the competitive equilibrium distribution of crop land and the socially optimum distribution of the agricultural activity. Von Thünen demonstrated that land rental rates would be greatest at the town itself, and rental rates would decrease to a zero rental rate at the outer edge of the cultivated lands. This land rental rate gradient, when combined with the shipping cost and yield characteristics of the various crops, will lead to concentric rings of cultivation; a bull's-eye pattern of agricultural development with the town in the center. High yield and high transportation cost agricultural goods would compose the innermost rings, and low yield, low transportation cost agricultural goods form the outermost rings. In equilibrium, the land rent gradient will evolve to induce farmers to produce enough of each crop to meet demand, and this, combined with the zero rental rate at the outermost edge of civilization, will combine to guarantee a unique equilibrium. This unique competitive equilibrium is pareto efficient.

This very simple exercise from von Thünen is now in its third century, and its importance to questions of economic geography cannot be overstated. Alonso (1964), for example, revived the von Thünen framework for the industrial age to explain the distribution of commuters around a central business district.

While von Thünen laid an elegant foundation for issues of economic geography, much of the work he inspired seems to have bifurcated into economics without geography and geography without economics.

Economics Without Geography

The field of urban economics is certainly the area within economics that has most directly attacked questions of geography and economic agglomeration. International economics, and particularly international trade theory, also has a strong tradition of spatial considerations; however, much of this work has explained economic agglomeration as a natural result of international variations in factor endowments. Hence, geography becomes a strictly exogenous driver of the distribution of economic activity, and distance matters in international economics only because barriers to factor mobility make them matter; if all factors moved freely in international economics, the distance between trading partners would cease to be much of an issue.

Mills (1967) and Henderson (1974) were among the first to tackle the question of factors driving economic agglomeration within a country, where all factors are (potentially) mobile. Mills described the evolution of the city as resulting from a tension between the external economies of scale acting to encourage agglomeration and diseconomies, such as commuting costs, that act to discourage agglomeration. Henderson pointed out that these tensions should serve to define an optimal city size in terms of the utility of a representative resident. Henderson explains the wide variation in the sizes of cities as resulting from the differences in the external scale economies of agglomeration in the industries of the cities in question. So, Henderson might claim that Detroit is bigger than Hartford, Connecticut because scale economies of agglomeration in automobiles are greater than scale economies of agglomeration in insurance. Each of Henderson's cities will coalesce around a single core industry, since external economies will tend to be strongest only within an industry, but diseconomies, like congestion costs, will tend to increase with city size, regardless of the composition of industries in the city. Paper mills will not locate in steel mill towns, and vice versa, since there is no external economy to take advantage of. However, there are congestion diseconomies to discourage such a location decision. Henderson's model also provides a framework to describe the evolution of new cities as population or technology changes act to move existing cities away from their optimal sizes.

As did von Thünen, Henderson derived a wonderfully simple and concise model of economic geography, at least after a fashion. But, the Henderson framework does still suffer from two serious shortcomings. First, Henderson's model relies upon a city corporation or a municipal central planner to take advantage of the production externalities; his theoretical framework simply does not allow for evolution of economic agglomerations through a free market process. Secondly, the Henderson framework tells us nothing of the spatial distribution of cities, which is ironic for a model of economic geography. The model allows one to explain the number of cities and the sizes of various cities, but it can tell us nothing about where the citieSs are or why they are where they are. If one were to apply traditional economic principles of perfect competition to a Henderson world, the cities should all locate in a concentrated geographic region, forming rings akin to the agricultural rings of von Thünen. This might be an accurate description of the Northeastern seaboard of the United States, but it is certainly not true in general. Thus, while there is a strong economic rigor to this and much of urban economics, the field largely maintains this characteristic of being quite "aspatial."

Geography Without Economics

The work of von Thünen, while extraordinarily insightful, begs a very obvious question: The farmers are where they are because the city is where it is, but why is the city where it is? It is this very question that inspired what became known as “central place theory,” developed by Walter Christaller (1933), which marks the earliest foundations of “regional science.” It is this theory and this field that marks the fundamental departure of regional analysis from the economic tradition.

Central place theory begins with a featureless plain occupied by an evenly dispersed, agrarian population. This agrarian population will require services, and clearly some of those services simply cannot be evenly distributed across the plain due to strong economies of scale. If these activities cannot be evenly distributed across the plain, then necessarily, hubs of economic activity will arise. While these economies of scale will lead to agglomeration, transportation costs will prevent absolute agglomeration. Hence, one might expect that the featureless plain will become peppered with centers of economic activity, cities, and towns (or “central places”) that provide manufacturing, administrative, and trade services to the evenly dispersed agricultural workers. Christaller's (1933) seminal contribution to the field was to produce evidence that there is, in fact, a hierarchy of these central places. A large number of small market towns, for example, are centered on a larger administrative center, and so on. Thus, the latticework of central place theory is really a more complex latticework of latticework; a repeating pattern akin to a fractal. Lösch (1940) was the first to give a theoretical form to this latticework. He proved that if the lattice of central places evolved in such a way as to minimize transportation costs, then the trade areas for each of the central places would be hexagonal with a central place at the center of each hexagon. Taken together, the work of Christaller and Lösch suggests a pattern of economic geography marked by a series of hierarchical nested hexagonal trade areas.

The work of Christaller and Lösch are certainly very intuitively attractive, and they also serve to set the intellectual landscape of much of the regional science research that follows. One will note that their work differs from that of von Thünen in one absolutely critical respect. Von Thünen's work demonstrated how the self-interested actions of individual economic agents can lead to a distinct spatial distribution of economic activity, and hence, fits very cleanly into the economic intellectual tradition. The work of Christaller and Lösch and their antecedents, on the other hand, tend to disregard underlying behaviors. Though I do not wish to in any way minimize the contributions of this field of study, regional science seems often to mistake an intuitively reasonable description of how the world *looks* for a rigorous description of how the world *works*. The mechanism of individual self-interest, for example, plays no roll in Lösch's description of pentagonal trade areas; instead, he begins with an unsubstantiated assumption of aggregate trade cost minimization and proceeds from there. While the answers provided by regional science are not entirely satisfactory to the economist, the questions that the field asks are extremely interesting, and it is truly surprising that economics neglected these issues for so long (Fujita & Thisse, 2002). Isard (1956) was responsible for introducing this rich German history of regional economic analysis to the English speaking world, and in the process established the field of regional science in the United States.

The Regional Science Tradition; Applicability at the Expense of Rigor

In introducing regional science to the English speaking world, Isard expected to nurture a new field of economics, one particularly suited to applications in regional planning, economic development, transportation planning, and the like (Isard, et. al., 1998). However, the field has instead tended to evolve away from the field of economics. Regional science has developed models that exhibit only very loose economic logic; in a very real sense, the field has sacrificed the theoretical foundations of mainstream economic thought for the sake of developing models to be used "in the field." Far from developing a set of fundamental theories, regional science has instead seen the development of a large set of tools for practical analysis. Economic purists might balk at the idea of basing real world decisions on what sometimes amounts to ad hoc models and atheoretical estimation techniques. Models that do not rest on sound economic theory might only bare a coincidental resemblance to reality in that there might be a fundamental disconnect between actual behavior and the model. Many of the tools of regional science do draw upon economics, but the application of economic foundations is likely too spotty, intermittent, and inconsistent to suit the tastes of economic purists. However, if the field is guilty of straying from behavioral foundations, it is certainly to be applauded for applying systematic thinking to practical problems of geography and planning. Many of the tools do reflect interesting behavior observed in the field, but largely unexplained by economics. Many of these tools, techniques, and discoveries might well inform the efforts of economists as they develop models of the geography of economic behavior.

Regional science has been responsible for developing much of applied location analysis, urban complex analysis, and spatial micro simulation. Regional science has also begun turning to general equilibrium analysis, and hence, has veered into the path of this research paper. In this area, regional science has developed tools such as spatial econometric analysis, gravity modeling, input-output modeling, social accounting analysis, and general interregional equilibrium. Each of these tools will come into play as we develop our model of the United States economy.

New Economic Geography; Rigor at the Expense of Applicability

While questions of spatial distribution have been central to regional science, it has, until recently, been decidedly on the periphery of economics. Most economic theory posits, for sake of simplicity, a world of constant returns, and constant returns preclude any interesting geographic agglomeration of economic activity. A world characterized by constant returns to scale in production, is a world where the increased transportation costs associated with centralized production are in no way offset by increased production efficiency. Such a world would necessarily be characterized by a uniform distribution of economic activity, “backyard capitalism,” where production is completely decentralized. A world of constant returns still allows a certain amount of economic agglomeration, but it is limited to so-called “first nature” differences. Coal mines will be located where the coal is; shipbuilding will be located where the water is, and so on. In this world, any economic agglomerations are driven exclusively by physical geography, and economic forces will drive the world to the greatest practical level of economic dispersion.

This is not at all like the world we live in. The real world is clearly characterized, to a huge degree, by economic agglomeration; agglomeration that simply cannot be explained away by differences in physical geography. Insurance, for example, is an industry that requires essentially no geographically fixed resources, and yet in the US, the industry is concentrated heavily in two cities (Hartford, Connecticut and Omaha, Nebraska). Internet companies have, for mysterious reasons, concentrated very heavily in the Silicon Valley, in spite of the resulting skyrocketing land rents and congestion. How has this happened?

Or equally mysterious, consider Mexico City. Mexico City is among the fastest growing urban area in the world, and yet there is no physical geographic feature that appears to drive this agglomeration. The city has no ports and no natural resource base. Indeed, it is essentially built on marshland, which would seem to make it a particularly poor candidate for economic agglomeration in a constant returns world.

The answer proposed by Fujita, Krugman, and Venables (1999) and many others, is quite simple. They posit that the real world is not characterized by the constant returns to scale much loved by economists; rather, it is characterized by a cumulative and self-reinforcing economic agglomeration process, which must necessarily be driven by increasing returns to scale.

Of course, accepting a world of increasing returns means accepting a world that is much more complex. Most notably, increasing returns precludes perfect competition. Increasing returns is also very likely to generate multiple equilibria, and the number of equilibria is likely to skyrocket as the number of regions and the number of economic agents being modeled proliferates. The proliferation of equilibria seems to be a particularly troubling issue to economic theorists, though this author does not see this as a serious problem. While a model of economic geography, characterized by increasing returns, might generate any number of potential equilibria, the state of the economy at a point in time could be used to determine the unique equilibrium (absent exogenous shocks) that will result. A rollercoaster, too, has a profusion of potential equilibria (stable ones at the bottom of each drop, unstable ones at the top of each rise or loop), and yet rollercoaster designers are perfectly capable of engineering a system that works consistently. Economies may not be so simple or predictable, but the same principle will arise in this paper as we begin to develop a regional economic geography model that is applicable to the real world.

The efforts to actually model increasing returns in some tractable way can be traced to the groundbreaking work of Dixit and Stiglitz (1977), which formalized the model of Chamberlinian competition and in the process developed the tremendously popular and useful Dixit-Stiglitz model. Though originally applied to industrial organization, the Dixit-Stiglitz model has since been applied in any number of economic fields, and in the past several years, has been central to "new economic geography."

At this point, the new economic geography literature has evolved a large number of theoretically intriguing models, designed to describe various aspects of the geographic forces at work in a world of increasing returns. The most comprehensive models have been laid out by Fujita, Krugman, and Mori (1999), Fujita, Krugman, and Venables (1999), and Puga (1999), but each of these make somewhat unrealistic assumptions for the sake of tractability by assuming away land constraints or removing capital stock from the production process. Most theoretical models resort to even more drastic assumptions for the purpose of uncovering specific forces of interest. Models that involve only two regions and one or two industries are extremely common, often with only one resource that is mobile between the two regions or with one immobile production sector. These models, as we shall see, provide remarkable insight into the mechanisms that might drive economic agglomeration and the spatial distribution of economic activity. However, they are simply too abstract or oversimplified to be used to develop a useful applied economic geography model of regional economies. It is the goal of this paper to, in some modest way, unite the theoretical findings of new economic geography with the existing tools of regional science to produce a model structure that is unique in its theoretical rigor and in its application to real world spatial economic dynamics.

Chapter 2

DEVELOPING A DATA FRAMEWORK: MERGING INPUT-OUTPUT AND SOCIAL ACCOUNTING

Tools for Unification: Input-Output, Social Accounting, Increasing Returns, and Gravity

Several approaches have been used to represent the macroeconomic interactions among sectors and, by extension, the analysis of impacts of alternative policies. Most general equilibrium models may be broadly grouped into the input-output impact analysis models characterized by Leontief (1941) and others, and the more advanced endogenous price, quantity and income computable general equilibrium (CGE) models. While the fixed price assumption of input-output models is clearly unrealistic, these models do, generally, include much more detail in terms of industry-industry interactions; and the fixed price assumption is not terribly problematic when one is interested in analyzing relatively small shocks to the economy where endogenous price changes are unlikely to be significant. While we are developing a CGE model, we will be incorporating the fine level of industry detail found in input-output models into our CGE framework. This, however, will require a serious reexamination of traditional input-output methods for organizing data and modeling economic interrelationships. In this chapter, we will first outline the basic data format involved in input-output analysis, and the implicit assumptions and shortcomings underlying that data layout. Next, we will examine the popular extension to input-output, called social accounting matrices (SAMs), and the improvements offered by this approach. Finally, we will develop a slightly different framework, a merged IO-SAM, that we feel includes the best of both approaches and subtly, but critically, improves on both.

Basics of Input-Output Analysis

Input-output analysis, attributed to Wasily Leontief (1941), has been used for assessing the impact of a change in the demand conditions for a given sector of the economy. The basic relationship in these models is represented by

$$X_{ij} = a_{ij} X_j \tag{2.1}$$

where X_{ij}, the amount of sector i output required for the production of sector j output is assumed to be proportional to sector j output X_j, and a_{ij} is the relevant input-output coefficient – the typical Leontief production function. If we sum this equation over all sectors and add in final demand F_i to the above equation, we have the basic input-output model:

$$X_i = \sum_{j=1}^{n} a_{ij} X_j + F_i \tag{2.2}$$

Equation (2.2) is further assumed to hold in first-difference form. An increase in final demand in a particular sector, ΔF_i, will necessarily increase production for that sector, which in turn raises the intermediate demand for all sectors. To produce these intermediate inputs, however, more intermediate inputs are required. Output in the various industry sectors continues rising through every additional round of intermediate demand. These increases become smaller, such that their total always has a limit (Sadoulet & de Janvry 1994). Equation (2.2) is frequently presented in matrix notation:

$$X = (I - A)^{-1} F \tag{2.3}$$

where X is the vector of outputs, F is the vector of final demands, A is the matrix of input-output coefficients, and I is the identity matrix. The matrix $(I - A)^{-1}$ then becomes the multiplier used to calculate overall changes in sectoral outputs caused by changes in final demand.

The traditional input-output analysis hinges on the crucial assumption that sectoral production is completely demand-driven; that is, there is always excess capacity in all sectors sufficient to meet the increased demand with no price increase. Because this assumption is likely to be unrealistic, input-output models are more useful as guidelines to potential induced linkage effects and as indicators of likely bottlenecks that may occur in a growing economy than as predictive models (Sadoulet & de Janvry 1994). These models are also much more useful when examining the impact of relatively small exogenous shocks where price impacts are likely to be small, rather than relatively large shocks. Input-output models are seriously constrained by their constant returns to scale production function with no substitution among the different inputs and prices that are assumed constant. Despite these shortcomings, the input-output approach is quite powerful, and remains to this day, the most popular impact analysis technique in applied regional economics (Isard, et. al., 1998).

One key problem arose with the application of Leontief's original input-output table configuration, which mapped industry output directly as intermediate inputs of other industries, as shown in figure 2.1. The problem concerns secondary products —commodities that fall outside the scope of the industry in which the establishment is classified. Under the original Leontief configuration, industry-to-industry transactions are denominated in terms of the output of the producing industry, effectively ignoring the commodity mix produced by that industry. If 5% of automobile manufacturer output is automobile parts, rather than cars, then in effect, 5% of every purchase from the automobile industry goes to the purchase of automobile parts, not cars.

Two traditional solutions to this subtle problem were implemented in developing input-output tables in the United States. When the industrial censuses on which U.S. input-output tables were based did not provide enough detail to identify the type of commodity, the value of the products was charged to an "unallocated" sector. In other cases, input-output tables introduced "transfers," which were nothing more than fictitious sales from the industry that produced the secondary product to the industries that were the primary producers of the commodities. This treatment moved the commodities to the correct industries, but also had the unfortunate effect of inflating the value of gross output. These were clearly not satisfactory solutions.

Selected interindustry transactions, United States, 1929

[In millions of dollars]

Distribution of outlays	Distribution of output (revenue)						
	...	Other iron and steel	Automobiles	...	Exports	Consumption	Total output
... ...	...	14	15	...	42	43	...
14 Other iron and steel	...	1,274	548	...	807	1,151	12,865
15 Automobiles	...	...	1,445	...	532	2,926	5,454
...	...	...	...	...	...	...	...
42 Imports	...	20	—	...	...	842	4,997
43a Wages and salaries	...	4,226	871	...	...	6,978	45,603
43b Capital and entrepreneurial services	...	1,347	496	...	...	7,175	26,194
43c Total services	...	5,573	1,367	...	...	14,153	71,797
Total outlays	...	13,667	5,734	...	5,230	75,646	251,502

NOTE: Dash indicates amounts smaller than 0.1 percent. Numbers associated with names of sectors are from Leontief's table.

SOURCE: Wassily Leontief, *Structure of American Economy, 1919–1939*, table 6.

Figure 2.1: A sample secondary product problem in the Leontief input-output configuration.

An elegant solution to this problem was proposed by Stone and Brown (1962). Instead of a single input-output table that maps industries directly into industries, they proposed construction of two tables – a "make" table which showed the output of commodities by industries, and a "use" table, which showed the commodities used by industry category, and by each component of final demand. This alternative design prevents any accounting irregularities and more closely fits the economic intuition of production functions, in that commodities enter directly into the production function of industries, rather than production functions being denominated in terms of the industry that produces the intermediate input, as was the case in the classic Leontief configuration. The make and use table design of input-output tables is the variant that is now in common use throughout the world. The basic layout of the make and use tables produced by the United States Bureau of Economic Analysis, which we will be using in our analysis, are depicted in figure 2.2.

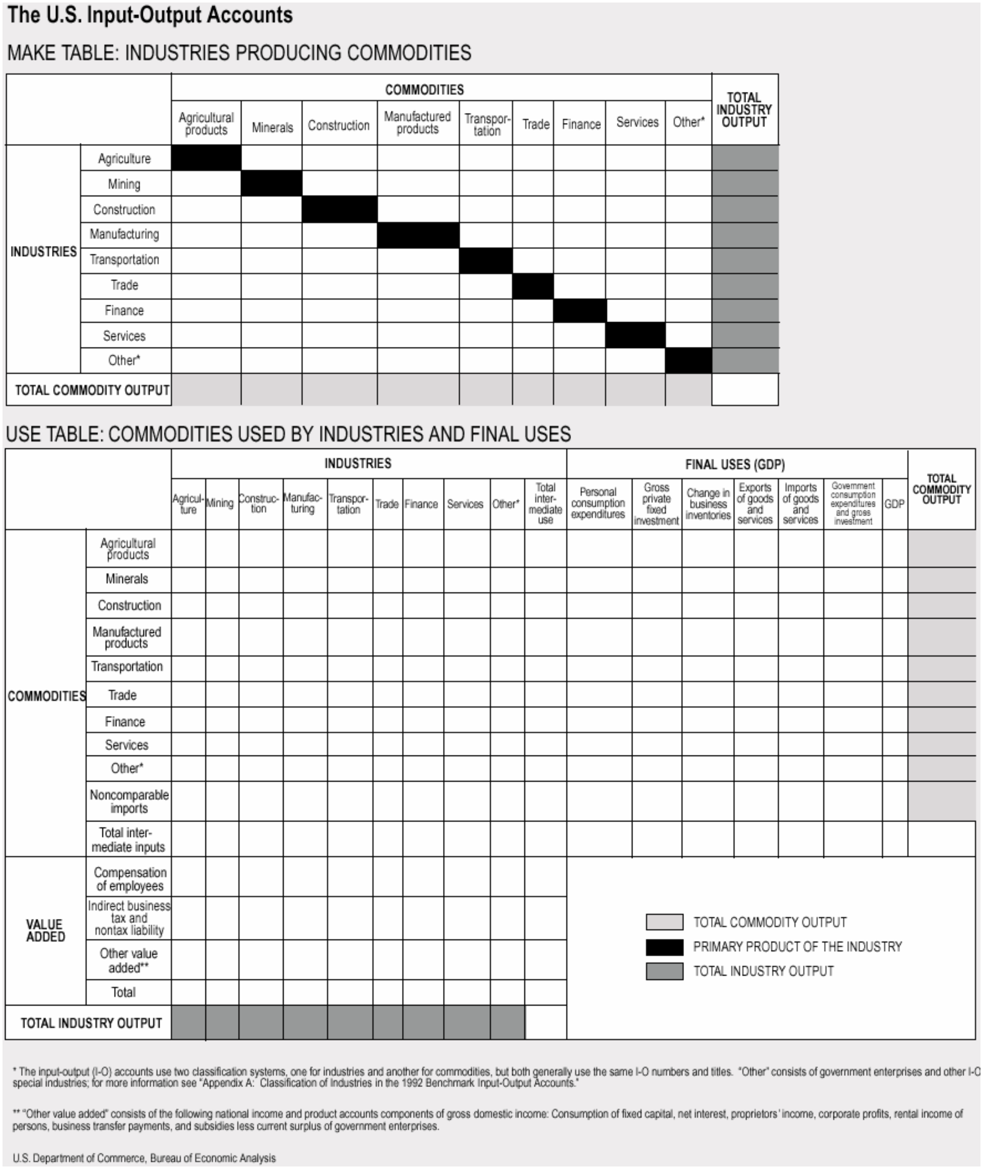

Figure 2.2: The current BEA. Make and use table configuration, as originally proposed by Stone and Brown (1965).

The make and use table configuration of input-output tables provides a remarkably detailed and complete picture of the interactions of industries. However, one other significant variation on the input-output model has been developed for the purpose of incorporating detail on transactions outside the industry-industry transactions that form the heart of input-output tables, and to create a comprehensive (in an accounting sense) picture of economic activity in a region (Pleskovic & Trevino, 1985). These "social accounting matrices" will be examined next.

Basics of Social Accounting Matrices

The social accounting matrix (SAM) is a tool closely related to national income accounting and input-output accounting and provides a conceptual foundation for examining both growth and distributional issues within a single analytical framework. A SAM can best be seen as a means of presenting, in a single matrix, the interaction between production, income, and consumption. It differs critically from input-output accounting in that it explicitly covers all transactions; input-output accounting explicitly details industry transactions, while leaving other transactions, such as the government sector and the household sector, implicit.

A social accounting matrix is a single entry accounting system wherein each institution or entity is represented by a column for all purchases and a row for all sales (Pyatt & Round, 1985). It is generally represented in the form of a square matrix, which brings together data on production and income generation by different institutions/entities on the one hand, and data about expenditure of these different institutions/entities on the other. In a SAM, sales are indicated as entries in the row accounts in which they are located and purchases are indicated in the column account of the purchaser. Each cell of the matrix identifies the volume of trade from the row element to the column element. Since all sales in a SAM must be accounted for by total purchases, the row total and the column total must be equal for a given institution/entity.

The data sources for a SAM generally come from input-output tables, national income statistics, and household income and expenditure statistics. Therefore, a SAM is broader than an input-output table or a typical national income account, showing more detail about all kinds of transactions within an economy. A SAM can provide a conceptual basis to analyze both distributional and growth issues within a single framework (Bendavid-Val, 1991). For instance, a SAM shows the distribution of factor incomes of both domestic and foreign origin, over institutional categories, and explicitly identifies any re-distribution of income over these categories. In addition, it shows the expenditure of these categories on consumption, investment, and savings. The fundamental purpose of a SAM is twofold: to organize information about the economic and social structure of a country over a period of time and to provide statistical basis for the creation of a plausible model capable of presenting a static image of the economy, along with simulating the effects of policy interventions in the economy. It is important to note that a SAM is not, in and of itself, a model of economic behavior, but it may serve as a foundation for input-output or general equilibrium modeling.

The number of rows and columns in a SAM is flexible, in accordance with the nature of an economy, the purpose for which the SAM is required, and the data available to populate the matrix. A well designed SAM could hypothetically be aggregated or disaggregated to any degree of specificity, while still remaining completely consistent. For any given account, and therefore for each particular row and column pair, the entries in the row express revenue for that account, whereas the entries in the corresponding column represent the expenditure side of the account.

All of the major components of the basic social accounting matrix are shown in Figure 2.3 (Pyatt & Thorbecke, 1976). It includes factors of production accounts, institution accounts (Households, Companies, and Government), an account for production activities and an account for the rest of the world. The first account is for the factors of production. The factors of production receive income from various production activities. Factor income is shown in the cell in row 1, column 6, and gives total value added (Gross Domestic Product, if the SAM is for a nation). Similarly, the row total for row 1 represents Gross National Product. It is also possible, here, to obtain the factorial distribution of value-added between the factors of production. The SAM explicitly demonstrates that “the stream of value added, from the production side, rewards the factors of production with wages going to different types of labor, rent going to land, and other resources, and profits to capital" (Pyatt & Thorbecke, 1976). Column 1 shows how the factor incomes are paid out to the providers of factor services.

Accounts 2 through 5 are the domestic institutions. As shown in Figure 2.3, there are three separate current accounts for institutions, including two accounts for the private sector (households and companies), and one account for government (account 4). In addition, there is a capital account for the domestic institutions, (account 5). Households have their own labor and capital, which they sell to the production sector (privately or publicly owned) and obtain factor income (wages and surplus).

			Expenditure							
			1	2	3	4	5	6	7	
			Factors of production	Institutions: Current accounts: Households	Companies	Government	Combined capital account	Production activities	Rest of the world combined account	Totals
Receipts	1	Factors of production						Value added payments to factors	Net factor income received from abroad	Incomes of the domestics factors of production
Institutions: Current Accounts	2	Households	Allocation of labour income to households	Current transfers between households	Profits distributed to domestic households	Current transfers to domestic households				
	3	Companies	Allocation of operating surplus to companies			Current transfers to domestic companies			Net non-factor incomes received from abroad	Incomes of the domestic institutions after transfers
	4	Government		Direct taxes on income and indirect taxes on current expenditure	Direct taxes on companies plus operating surplus of state enterprise		Indirect taxes on capital goods	Indirect taxes on inputs	Net non-factor incomes received plus indirect taxes on exports	
Institutions	5	Combined capital account		Household savings	Undistributed profits after tax	Government current account surplus			Net capital received from abroad	Aggregate savings
	6	Production activities		Household consumption expenditure on domestic goods		Government current expenditure	Investment expenditure on domestic goods	Raw material purchases of domestic goods	Exports	Aggregate demand = gross outputs
	7	Rest of the world combined account		Household consumption expenditure on imported goods			Imports of capital goods	Imports of raw materials		Imports
		Totals	Incomes of the domestic factors of production	Total outlay of households	Total outlay of companies	Total outlay of government	Aggregate investment	Total cost	Total foreign exchange receipts	

Figure 2.3: A typical social accounting matrix.

This income is used by households for consumption, savings, and investment. The private corporate sector receives surplus income; it invests, but does not consume and has transactions with the rest of world. The public sector levies direct and indirect taxes, and both consumes and invests. The combined capital account, then, serves as something of a ‘residual’ account.

Entries at the intersection of rows and columns 2 and 4 are current domestic transfers, such as direct taxes on income, which are paid to government (row 4, column 2), and dividends paid to domestic shareholders (row 2, column 3). Households and companies potentially receive transfer income from abroad (intersection of row 2-3 and column 7). The total current income of domestic institutions is shown in row 2 and 4 and their savings in row 5. Savings are shown in row 5 as transfers from the current accounts of institutions to their combined capital account. For instance, domestic savings are shown in the intersection of row 5 and column 2 for households. Aggregate savings are the sum of household savings, undistributed profits after tax, government current account surplus, and net capital received from abroad. This is spent in column 5 to finance investment in the economy. As shown in Table 1, after subtracting raw material purchases of domestic goods (intersection of row 6 and column 6), the total of row 6 gives aggregate demand or gross output.

The final account to consider is the external account, number 7. It does not invest (this is included as a part of investment by the private corporate sector), but it does serve as a competitive source of inputs into the domestic production process.

The SAM is an approach for data organization, reconciliation, and descriptive analysis of the structure of the economy; it is a matrix realization of the basic macroeconomic circular flow diagram. “The most important feature of a social accounting matrix is that it provides a consistent and convenient approach to organizing economic data for a country and it can provide a basis for descriptive analysis and economic modeling in order to answer various economic policy questions” (Pleskovic & Trevino, 1985). A SAM can be used for macroeconomic planning in two ways: first, a SAM can provide a framework for the organization of information related to economic and social structures of a country's economy. Second, a SAM can serve as a database for a model of the economy under consideration (Jensen, 1990).

Pyatt and Round (1988) argue that a SAM informs the economic policy debate and should not be seen as a 'once and for all effort'. This is because underlying any general equilibrium model, there is a SAM, whether it is explicit or implicit. They suggest that the coefficients of its rows and columns, and consistency of the same, are essential to testing the validity of macro-economic models. If the model assumes certain relationships between sectors or institutions, the SAM could be used to test the validity of these based on the coefficient relationships which must hold ex post. That is, the sum of the resultant proportional distribution of the coefficients in the rows and columns must be equal to one.

Once again, consider the basic thought exercise employed in examining the input-output framework: let us suppose that there is an exogenous increase in external demand. This would first have an impact on the production account. This would result in the need for more factors of production from the household and private corporate sectors who own them. Their sale to the productive process would result in more income accruing to, and subsequently more demand from, the owners of these factors. This would generate additional demand from the productive process, more direct and indirect taxes would accrue to the government, and more demand for imported inputs into the production process or for general consumption. This series of events 'rippling' through the economy are adequately captured by a SAM because of its consistency requirements. The end result of all these changes, which like the input-output have less impact in later rounds, is to produce a new SAM for the economy.

Because a SAM that conforms to the above description ensures that the underlying macroeconomic model is internally consistent, a SAM will be one of the key touchstones in developing our model. That said, the basic layout of the SAM will be slightly reconfigured and fundamentally reconceived. This reconception, the author feels, is much more conducive to a tractable, applied economic geography model.

A Merged IO-SAM Framework

The beauty of the input-output framework originally developed by Leontief is its utter simplicity – each industry sells its output to itself, to other industries, or to final demanders. So, on a single table, one can capture all of the activity in an economy. Stone and Brown, however, caught a flaw in Leontief's reasoning. The Leontief input-output table implicitly failed to recognize that every industry uses a mix of commodities, and that every industry makes a mix of commodities; the commodities are a necessary component to accurately and explicitly describe the behavior of the system. Mathematically, under the make and use table configuration of Stone and Brown, "industries" become nothing more than a transformation system that converts a menu of commodities and factor inputs into a menu of commodity outputs. Generally, the Stone and Brown input-output tables can easily be used to model industry behavior using either Leontief or Cobb-Douglas production functions. In fact, the configuration is particularly well suited to Cobb-Douglas functions, as all cells are simply a record of budget share, which is a constant in Cobb-Douglas production functions.

However, these traditional input-output tables still have very little to contribute when we attempt to model anything beyond the industry-commodity-industry interactions. Particularly, the final demand components are simply floating in the rightmost columns of the use table, and the factor components of the industrial process are hovering, detached, in the bottom rows of the use table (See Tanner & Hearn, 2005).

This points to the input-output shortcoming that social accounting matrices attempt to address – that there are a significant set of interactions that are not accounted for in the input-output table format. Household, government, and capital markets are explicitly introduced under the SAM framework, and a host of behaviors such as taxation, intergovernmental transfers, etc., are included in this alternative data structure. In input-output make and use tables, it is clear that there is a relationship between the value added rows and the final demand columns, in that the total of the value added cells in the use table must equal the total of the final demand in the make table, but the nature of the relationship is left to the imagination. The SAM framework has the advantage of being absolutely comprehensive; every type of transaction is accounted for in some cell of a SAM matrix, and the matrix is potentially endlessly expandable; it is limited only by the data available and the needs of the researcher. One might imagine a comprehensive SAM in which every individual, every business, every government entity, in short, every agent, has it's own row and column in the SAM. The result would be a matrix explicitly showing every financial interaction in the economy.

But the SAM framework is comprehensive at the expense of being incomprehensible, at least when one attempts to develop any interesting rules governing the behavior of the plethora of agents implied by the SAM. This becomes even more evident when one attempts to develop rules (equations) governing the interregional interactions of SAMs. SAMs are lovely for accounting work and frustrating for economic geography work. As we shall see, the problem stems from the fact that while SAMs are comprehensive from an accounting perspective (every transaction shows up in some cell in the matrix), it is not complete in an economic sense in that each cell does not represent a unique exchange of a commodity for money, as it does in input-output make and use tables. The model developed here will begin with an alternative framework that draws on the comprehensiveness of the SAM and the simplicity of the Make and Use input-output tables. The end result, it is hoped, will be more elegant than either approach.

The framework relies on taking the traditional economic concept of the circular flow diagram absolutely seriously, and on discarding the artificial primacy given to the idea of factor inputs to production. The framework we propose involves viewing the economy as nothing more than an endless process of converting menus of commodities into menus of commodities.

Businesses convert a menu of commodities into a menu of commodities. Labor converts "final goods" (a misleading term for the model we develop, as there is nothing "final" about them) into labor (a commodity like any other). Even unemployed labor can be considered in this light, as an entity that converts consumer goods into transfer payments. Government – this is perhaps the biggest conceptual hurdle – converts purchases of commodities into government goods. While an admitted abstraction, throughout our model development, we shall treat government goods as rival in consumption (demanders will consume the good in proportion to their share of aggregate regional demand for government goods); the government goods market will not be truly private, however, in that governments may overproduce or under produce government goods relative to the market demand for those goods.

We can now see how we might merge the input-output and SAM methods of conceptualizing an economy as a unified system. Imagine a make table where the row elements include all of the various industries generally included in make tables, but also includes all of the various "industries" implied in the SAM framework. This make table will include one or more government rows where commodities produced by government entities will be found. We can add one or more "speculator" rows, which will be used to produce physical capital, as we shall see in a moment. We can also add several columns to the make table. We will add one or several labor commodities; this labor is produced primarily by the one or several labor industries we added as rows in this table. We also add a "financial capital" column to the make table, representing factors such as dividends, interest, and rent earned by households through the process of saving.

We may add one or more transfer payment columns to represent the "commodity" produced by unemployed labor. Conceptually, we are simply saying that unemployed labor is very clearly producing a commodity; it may be difficult to picture what that commodity is, but the very fact that they are being compensated is enough evidence to intuit the presence of the commodity itself, much as an astronomer can intuit the presence of a neutron star based entirely upon the fact that there is "stuff" falling into it. One might debate the wisdom or rational behind the transfer payments, but what is beyond doubt is that unemployed labor produces some commodity, which some entity or entities are purchasing based upon some decision making criterion (optimizing function); that is all we care about for this modeling exercise. Similarly, we may add one or several government commodities, produced by the government "industries," added as rows to the make table. Once again, we can intuit the presence of the commodity from the presence of the transaction (taxes). In a regional framework, we might even say something of the value of state and local government commodities by relying on a Tiebout-like behavior of "voting with one's feet." We will also add columns for physical capital, which will be the commodity produced by the investor "industry" we added as a row in the make table.

A use table can be constructed along similar lines. As with the make table, we will add one or several labor "industries," unemployed labor, government, and speculators as columns in the use table, and the commodities of labor, financial capital, transfer payments, government taxes and fees, and physical capital as rows to the use table. The labor industry (industries) will use a mix of commodities once relegated to the final demand portion of the use table. Unemployed labor and government, similarly, will use a mix of commodities from the final demand portion of the traditional use table.

The role of the proposed "speculator industry" is a bit more obscure and deserves a brief explanation. The speculator industry will use the mix of commodities identified in the traditional use table under investment final demand, in addition to the financial capital good, to produce the physical capital good(s) identified in the make table. The speculator industry is something of a "ghost in the machine," in that it is a mechanism used in the model we will develop to insure that the presumably quite mobile financial capital commodity flows through inexplicit intermediaries to purchase presumably relatively immobile physical capital. While it may be that money I invest goes to the purchase of a conveyor belt used by a California assembly plant, the likely mechanism is that I (or my financial intermediary) provided my mobile financial capital to a California speculator (which may or may not be the business itself) who purchased the conveyor belt in California. What decidedly did not happen, was that I did not use my savings to purchase a conveyor belt, which I then shipped to California. As we are developing an economic geography model of the United States, it is critical that we accurately model where demand occurs, and the introduction of the speculator intermediary helps facilitate this. Finally, industries, in addition to using the commodities identified in the traditional input-output table, also use labor, physical capital, and government commodities, which are traditionally given artificial primacy as value added components in the use table. Figure 2.4 outlines the framework for this proposed comprehensive SAM/IO data structure. Note that the gray cells in the figure represent areas that are likely to contain either zeros or insignificantly small transactions. Also note, that the use table leaves open the possibility that government goods will enter into the use table of producers, labor, and financial capital. This will be explored in more detail as we begin to develop the model that will flesh out our data structure.

It is initially unsettling to imagine a model framework with, essentially, no factor inputs and no final demand. Those things, which are classically considered factors and final demand, will still be presented in this framework, but they hold no special place; they are just more commodities, and/or more industries. Industries, themselves, also might be viewed in a new way. Every industry in the framework is merely a transformation function for converting a menu of commodities, as identified in the industry's column in the use table, into a different menu of commodities.

Make Table	Producer Commodities	Labor	Transfer Payments	Government Goods	Financial Capital	Physical Capital
Producers						
Employed Labor						
Unemployed Labor						
Government						
Investors						
Speculators						

Use Table	Producers	Employed Labor	Unemployed Labor	Government	Investors	Speculators
Producer Commodities						
Labor						
Financial Capital						
Transfer Payments						
Government Goods						
Physical Capital						

Figure 2.4: A proposed merged SAM/IO framework for the make and use tables.

Now that we have outlined and motivated the data structure that we will use in our model, the next chapter will explain the nuts and bolts procedure used to populate the merged IO-SAM framework for the United States economy and, more importantly, for populating the merged IO-SAM framework for every county in the United States.

Chapter 3

POPULATING A MERGED IO-SAM FRAMEWORK FOR U.S. COUNTIES

Filling Out the Framework

In the previous chapter, we outlined a framework for a merged IO-SAM database; it is this data format and structural framework that we will rely upon as we develop our regional model of the U.S. economy. Before we can do anything with this framework, however, we must go through the grueling process of populating the data framework. In this chapter we will describe, in detail, the process used to generate a merged IO-SAM matrix for every county in the United States; it is this set of 3,110 merged IO-SAMs that will be used to estimate regional trade flows in chapter 4, and which will be used to develop our computable general equilibrium model in chapter 6.

Generating Employment Data

As described in the previous chapter, cells in the merged IO-SAM framework record the total quantity of commodities produced or consumed by each industry; hence, employment never enters into the merged IO-SAM at all. However, employment data plays a key roll in calculating the output of industries at the regional level. Because of this, it is the best starting point in populating the data framework.

To populate the merged IO-SAM, first employment at the county level in the United States is estimated at the five digit NAICS code level of detail (a total of 709 industries). Employment at the county level is estimated using two primary data sources, the Department of the Census County Business Patterns (CBP) data series and the Bureau of Economic Analysis' Regional Economic Information System (REIS).

CBP data is generated by the Department of Census from three primary data sources: the Bureau of the Census Economic Census, the Bureau of the Census Annual Survey of Manufacturers, and the Internal Revenue Service Quarterly Payroll File. The annual employment data reported in CBP is based on first quarter employment and is, therefore, a point-in time estimate and not an annual average employment estimate.

CBP employment data represents the number of workers on the payroll during the pay period including the second week in March. An employer who pays on more than one basis reports the sum of the number of workers on each type of payroll for the period. The employment count includes all corporation officials, executives, supervisory personnel, clerical workers, wage earners, pieceworkers, and part–time workers. Workers are reported in the state and county of the physical location of their job. Persons on paid sick leave, paid holiday, paid vacation, and so forth are included, but those on leave without pay for the entire payroll period are excluded. Persons on the payroll of more than one firm are counted in each firm, so employment is a measure of the number of jobs, rather than the number of employed people. The employment count excludes employees who earned no wages during the entire applicable period because of work stoppages, temporary layoffs, illness, or unpaid vacations, and employees who earned wages during the month, but not during the applicable pay period. County Business Patterns data is released annually on an approximate 2.5 year lag, and includes the number of employees at the United States, regional, state, and county level of geographic detail, and at the one, two, three, four and five digit NAICS code level of industry detail.

As with many such federal government data sources, CBP data is subject to non-disclosure rules. Any data that may disclose details of the operation of a single firm are suppressed in the public release of CBP, which at this fine level of industry and geographic detail, introduces a large number of suppressed data points. However, the CBP series is unique in that when employment data is suppressed, a range is specified for the employment number. In addition, CBP reports a breakdown of the number of firms by five digit NAICS category by county and by size class, regardless of whether the precise total employment number is suppressed.

The traditional method used by researchers to fill in data suppressions typically involves a three step process (Sechrist, 1986):

1. Initially estimate the value of each missing data point by using the sum of the midpoint values of the number of establishments by employee size class.
2. The five, four, three, two, and one digit NAICS data for any given region are summed from the bottom up to make initial adjustments to the non-disclosed elements, which will guarantee that they meet the summing-up condition that all five digit NAICS industries sum to their four digit parents, all four digit NAICS industries sum to their three digit parents, and so on.
3. The county, state, regional, and United States data for every NAICS code are summed from the bottom up to make final adjustments to the non-disclosed elements, which will guarantee that they meet the summing-up condition that employment for all counties in a state must sum to the state total, employment for all states in a region must sum to the region total, and the employment for all regions must sum to the United States total.

To date, every researcher who has filled CBP data has used some variant of this basic procedure, but the process fails to take full advantage of the information available in all of the various ranges for all of the suppressed data. Instead of replacing the range with an estimated value and then massaging the data until it is internally consistent, the suppression estimation procedure used here concentrates on narrowing the minimum and maximum values of the range for every suppressed value. In broad terms, the steps are as follows:

1. For every suppressed data point, the minimum (maximum) value of the suppressed range is compared to the sum of the minimum (maximum) values of the number of

establishments by employee size class. If the former value is smaller (larger) than the latter, the minimum (maximum) is adjusted upward (downward) accordingly. This step alone, generally and dramatically narrows the range of possible employment values.

2. In a procedure essentially identical to step 1, the minimum (maximum) value of each suppressed four digit NAICS code is compared to the sum of the minimum (maximum) values of all of its 5 digit NAICS code children. If the former value is larger (smaller) than the latter, the minimum (maximum) is adjusted upward (downward) accordingly. This is repeated at the three, two, and one digit NAICS level for every region.
3. As one might anticipate, the minimum (maximum) value of each suppressed state level data point is compared to the sum of the minimum (maximum) values of all of its counties. If the former value is larger (smaller) than the latter, the minimum (maximum) is adjusted upward (downward) accordingly. This is repeated at the regional and U.S. level.
4. Next, the process of steps 2 and 3 are "repeated in reverse;" the minimum (maximum) value of each suppressed regional level data point is compared to minimum (maximum) United States value minus the sum of the minimum (maximum) values of all of the other regions, for every NAICS code, and the appropriate adjustment to the range is made. This is repeated with the state and county level and then working down through the one, two, three, four and five digit level of NAICS detail.
5. The process outlined in steps 2 through 5 is repeated until successive iterations do not narrow the range for any NAICS code for any region. At this point, the range for most suppressed values has narrowed dramatically. Ranges narrowing from 400 employees to less than 20 are common.

6. Only at this point are ranges replaced with midpoint values, which are then RASed to hit all known total values (while keeping every unknown value within its range), to guarantee an internally consistent series.

The process outlined above has several advantages over other procedures. First, it takes full advantage of all of the data provided by the ranges of the suppressed data at all levels of economic and industry detail. Secondly, the process guarantees that no estimated value can ever stray outside the range dictated by all of the various specified ranges. Finally, the process of narrowing the range of values is completely path-independent; that is, the logically consistent ranges that are estimated are the same, regardless of whether the process begins with the finest level of industry and geographic detail and works up, or begins at the broadest level of detail and works down.

The end result of this process is a complete, "unsuppressed" and internally consistent employment estimate for every five digit NAICS code covered by CBP for every county in the United States.

County Business Patterns, however, does not report employment for every industry category, nor does it report, strictly speaking, every job. County Business Patterns excludes a small number of workers, most notably sole proprietors, as well as some NAICS codes, specifically those related to agriculture and to government. To ensure that the data includes estimates for these workers and industries in every county, all County Business Patterns estimates are scaled to match the employment numbers (at the one digit NAICS code level of detail for counties, and the two digit level for states) reported by the Bureau of Economic Analysis' Regional Economic Information System (REIS), which includes all employment in each region, although only at a broad level of industry detail. The procedure for filling data suppressions in the REIS data series is much more conventional in nature; a full description of the process can be found in appendix A.

Generating Wage Bill and Labor Income Data

Wage Bill data, which will ultimately be used both to populate the regional "labor industry" output in the model, as well as to determine output of most of the other industries, is derived from the same sources and uses the same techniques as the employment data described above. The primary data sources are, once again, the Department of the Census CBP data and the Bureau of Economic Analysis' REIS data. As with employment, CBP reports total annual payroll for each NAICS code up to the five digit level of detail. For the United States and for every region, state and county, the total payroll data is subject to suppressions for privacy reasons. Also, as with employment, suppressed wage data is replaced with a range value. The procedure used for filling and guaranteeing internal consistency of this wage data is precisely the same as the procedure used to estimate suppressed employment values.

As with the employment estimates, all CBP wage bill data, estimated and otherwise, are scaled to match the wage bill data reported by the Bureau of Economic Analysis' REIS, which includes all wages in every county and state at the two digit NAICS level of detail (note that REIS employment data was only available at the one digit level of detail). Wage bill values for government and agriculture sectors are used directly from the REIS data. It is also worth noting, that because REIS accounting is consistent with the Bureau of Economic Analysis National Income and Product Accounts (NIPA), comparisons and/or incorporation of other NIPA data is also feasible using this data.

Proprietor and other labor income, which includes all other forms of employee compensation, is distributed to industries and regions by first exploiting NIPA data on other labor income by industry. NIPA reports the total national other labor income by industry, which is used to calculate the ratio of proprietor and other labor income to wage and salary income for each industry. This ratio is then used to calculate an initial estimate of other labor income in each industry in each region. Once the initial estimates from the NIPA ratio are calculated for each industry in each region, the totals for all industries in each region are scaled to match the total proprietor and other labor income reported in each region by REIS.

Generating "Value Added" and Output

Note that value added, in the header for this section, is placed in quotes. This has been done to remind us that, under this data structure and regional modeling concept, the idea of "value added" is artificial, at least insofar as it implies primacy or a fundamental difference between "value added" components of the economy and "intermediate inputs." Value added components are key to populating the database for this model, as a result of the available data sources, but should not be viewed as conceptually being any different from any other commodities.

All estimates of "value added" and output in the model are driven by data from the BEA input-output benchmark and annual tables and the National Income and Product Accounts. The BEA input-output benchmark and annual tables divide value added into four components of interest in developing the model: employee compensation, proprietor income, other property income, and indirect business taxes. As described above, 5 digit NAICS code estimates of employee compensation, and proprietor and other labor income, have already been generated, which covers two of the four components of value added.

Indirect business taxes are taxes that are incident upon the producer during the normal operation of the business and consist, for the most part, of excise and sales taxes paid by individuals to businesses. Indirect business taxes do not include any taxes on profits or income. Other property income includes all payments of interest, rents, royalties, and dividends, as well as profits. This includes payments to individuals in the form of rents received on property, royalties from contracts, and dividends paid to shareholders, as well as retained corporate profits.

The procedure used to estimate each of these components is essentially the same, and must begin by generating a consistent annual input-output table for every year of interest in the model. We begin with the BEA benchmark input-output tables, which are only produced for years ending in 2 or 7. These are first converted from dollar amounts to proportions (that is, they are converted such that all rows and columns sum to one, instead of to the total dollar amount of commodity or industry output) and are linearly interpolated to generate initial estimates of input-output tables for intermediate years. These input-output tables are then "broken out" into full five digit NAICS code detail, under the assumption that the ratios of inputs for all NAICS codes within a given BEA input-output row/column are identical. These estimated input-output tables are then RASed to match the data reported in the much less detailed BEA annual input-output tables.

The Bureau of Labor Statistics produces input-output tables every even numbered year, and these, too, are converted such that all rows and columns sum to one, instead of to the total dollar amount of commodity or industry output, and are linearly interpolated to generate an estimated input-output table for each odd-numbered year. The Bureau of Labor Statistics input-output tables have two characteristics that are quite convenient when developing the model. While they have less detail in terms of value added components (they only report a single "value added" component, which is inadequate for our objective), they include much more detail in terms of "final demand" components. In addition, every year that a BLS input-output table is released, the BLS also releases an estimated input-output table for eleven years out, which is designed to capture their estimate of the roll of technological change over that time horizon. For forecasting purposes in our model, this is indeed an attractive characteristic. The same linear interpolation that is used to estimate BLS input-output tables for odd numbered years prior to 2002, can also be used to estimate annual BLS input-output tables for 2003-2011 using the BLS input-output tables for 2002 and 2012. Note that the BLS table has quite deliberately NOT been broken out into a full five digit NAICS input-output table.

Once the annual BLS input-output tables and the annual BEA input-output tables have been produced, the more detailed BLS input-output table "final demand" (just as artificial a concept, in this framework, as “value added”) are excised from the BLS tables, scaled to match the BEA table final demand components, and these final demand components then replace the BEA input-output table final demand components. At this point, each annual BEA input-output table (which we have already broken into 5 digit NAICS industries), is scaled to match the annual changes reported in the BLS input-output tables (which, critically, has not been so disaggregated). This process effectively fuses the greater dynamic detail of the BLS input-output table to the greater industry and “value added” detail of the benchmark BEA input-output table, and provides an input-output table for every history year and every forecast year through 2012. Forecast years after 2012 are modeled using the 2012 input-output table. Once the single, unified set of annual input-output tables is produced, each year is scaled to match the National Income and Product Accounts final demand totals for that year. Input-output tables for forecast years are rescaled to match the forecast from our US economic model, which is described in appendix B.

All of this complication is necessary to calculate the indirect business taxes and other property income components of value added, as well as industry output, but will thankfully be used for many other components of the data structure as well. Once the final annual BEA input-output table has been estimated for each year, the ratio of indirect business taxes to employee compensation and proprietor income is calculated, as is the ratio of other property income to employee compensation and proprietor income and the ratio of output to employee compensation and proprietor income. Once these ratios are calculated, the value of output, indirect business taxes, and other property income for each industry in each region is calculated by applying the appropriate ratio to the total wage and salary disbursements and other labor income already calculated for each industry in each region. Thus, the total labor and proprietor income becomes the determinant of region output. Others have scaled similar estimates to match the values reported at the state level by the BEA’s Gross State Product Originating data series; however, the numbers reported in this series are derived, rather than being directly reported from a data source, and hence, are not used in this model. Once "value added" and output are calculated for each industry, the output is allocated to commodities according to the proportions dictated by the national make table. This amounts to an assumption that the commodities produced by each industry are truly joint in the production process, and dictated by a uniform production function for all firms in that industry.

Two industries receive special treatment, as they will both figure prominently in the behavioral equations in our model: the "real estate" industry (NAICS code 531) and the "owner occupied dwellings" industry, which is not identified in the NAICS coding system, but is rather a constructed industry used in the BEA and BLS make and use tables to guarantee compatibility with NIPA. These industries are critical for the model, in that they include land values, which is the one fixed geographic commodity in our model.

The total output of the real estate industry is the total sales (and rentals) of all goods and services related to real estate, just as with every other industry. Unlike other industries, however, the "other value added" component is a huge share of the industry's output, and virtually all of the "other value added" component of real estate reflects the value of the land sold and/or rented. As such, the real estate industry will be split into two separate industries. The first will be a "real estate less land" industry, which uses all of the intermediate inputs of the real estate industry identified by the input-output table, except for the value added component, to produce a "real estate less land" commodity. The second industry, "real estate land" will use exclusively the "other value added" component of the real estate industry to make a "land" commodity. All industries that use the real estate commodity in the raw input-output table will see their real estate use split, proportionately, into use of the two new commodities.

The "owner occupied dwellings" industry is particularly odd, in that it makes an industry of owning property. The use table column for this industry includes expenditures by property owners on inputs used for property improvement, but is dominated by a value for imputed rent, which once again, forms the other value added component for this industry. As with the real estate industry, the "owner occupied dwellings" industry will be divided into two components, an "owner occupied dwellings less land" industry that uses all of the intermediate inputs except other value added to produce an "owner occupied dwellings less land" commodity, and an "owner occupied land" industry, that also uses the other value added component of the "owner occupied dwellings" industry to produce an "land" commodity. All industries that use the original "owner occupied dwellings" commodity in the raw input-output table, will see their "owner occupied dwellings" commodity use split, proportionately, into use of the two new commodity categories. The two land industries are then fused to create our single land industry, which produces the single land commodity.

The distribution of output for those producers, not included as industries at all in the traditional industry categories, remains to be dealt with.

Total output of the "employed labor" commodity in the U.S. is given by the NIPA total labor value added; the "employed labor" industry will be the sole producer of the "employed labor" commodity. This output of the employed labor commodity is allocated among the counties in proportion to each county's share of total national earned income by place of residence as reported by the REIS data series. The earned income by place of residence concept adjusts income earned at jobs within a county to include income earned by those living in the county, but not working in the county, and then subtracts income earned in the county by those not living in the county. As we shall see when we develop the behavioral equations, labor is "produced" in the county of residence and traded to the county of employment, much like trade in any other commodity. By this logic, the output of the labor commodity is allocated according to the county of residency of the worker (i.e., the employed labor industry). Ultimately, labor could be further disaggregated by occupation using BLS occupation by industry data, but this is beyond the scope of this incarnation model.

The “unemployed labor” industry is the sole producer of the “transfer payments” commodity. The model logic presumes that the presence of the transfer payment implies the presence of some commodity. Transfer payments are allocated from the total transfer payments reported by NIPA, to the counties, according to the counties’ share of total U.S. transfer payments, as reported in the REIS data.

The “investors” industry is the sole producer of the “financial capital” commodity; this is the commodity used entirely by the speculator industries. Financial capital is allocated from the total dividends, interest, and rent reported by NIPA, to the counties, according to the counties’ share of total U.S. dividends, interest, and rent, as reported in the REIS data.

Recall that the federal government “commodities,” and indeed all government commodities, are defined by the tax revenue collected. Just as with the transfer payments commodity, we are inferring the presence of the commodity from the existence of the payment. The total output of the federal government commodity is taken from the NIPA reported federal government revenue, and that output is allocated to the counties according to each county’s share of the total federal government wage bill. As we shall see, there will be trade in the federal government commodity, just as in every other commodity. For example, Washington, DC will be a huge exporter of the federal government commodity, producing some set of federal government goods for export to the rest of the country, for which the rest of the country is paying as reflected by county federal government tax payments.

State and local governments produce the “state government” and “local government” commodities, respectively. Total US output of the state and local government commodity is given by the NIPA reported total state and local government expenditures. This state and local expenditures total is allocated to the individual states according to the total state and local government expenditure reports for each state, which is produced by the Bureau of the Census government revenue data series.

These state level totals are then allocated to the counties according to the county's share of the state government wage bill and the county's share of the state total local government wage bill. As with federal government, trade in the state and local government commodities will take place, so, for example, state capitals will export state government commodities across the state.

There will be two categories of "speculators" in the model: residential speculators and non-residential speculators. The aggregate output of residential speculators for the U.S. is given by the NIPA total residential fixed investment. To allocate the output of the residential speculators industry to the counties, a simple metric is calculated. For each county, the one year change in total disposable personal income is calculated and this is added to .0725 times the one year lagged value of disposable personal income; where the calculated value is negative, it is truncated to zero. This value represents the approximate gap between actual residential capital in the region, and the desired residential capital in the region; the desired level, in a Cobb-Douglas sense, would be proportional to labor demand for capital and the level of standing capital would be the level that existed last year (proportional to last year's income), less depreciation (assumed, in accordance with BEA assumptions, to be 7.25%). Once this is calculated, the output of the residential speculators industry is allocated to the counties according to each county's share of the total metric described above.

Allocation of the output of the nonresidential speculators industry to the counties proceeds along similar lines. For each county, the one year change in total "other value added" for all industries is calculated, and this is added to .1275 times the one year lagged value of total "other value added" for all industries for the county; where the calculated value is negative, it is truncated to zero. As with residential capital, this value represents the approximate gap between actual non-residential capital in the region and the desired non-residential capital in the regi on, which is similar to the residential capital calculation, with a higher depreciation rate of 12.75% (once again, selected in accord with BEA assumptions). The output of the non-residential speculators industry is allocated to the counties according to each county's share of the total metric described above. As we shall see, distinguishing between the "investor" industry/commodity and the "speculator" industries/commodities allows us to separate the presumably quite mobile financial capital from the largely immobile physical capital.

Finally, recall that when we spilt the real estate industry/commodity and the owner occupied dwellings industry/commodity into two categories, the resulting land industry was left with no employees. Also, the "owner occupied dwellings less land" industry has no employees. As such, the output of these industries has yet to be allocated.

The output of the "owner occupied dwellings less land" industry will be distributed to the counties in direct proportion to each county's share of total demand for this industry; the demand distribution will be discussed in the following section. This distribution, we shall see, will have the effect of producing no inter-county trade in the "owner occupied dwellings less land" commodity.

The land industry/commodity faces intrinsic physical limitations associated with the region where they are located. The output of this industry is distributed to the various counties in direct proportion to the county's share of total U.S. land area. This will amount to assuming that, while land cannot be traded between regions, the share of land devoted to residential and nonresidential uses within a region can "float" freely.

At this point, we have constructed a complete, merged IO-SAM make table for every county in the United States. Now, we must construct a matching set of county level, merged IO-SAM use tables.

Generating Commodity Demand by Industry and by County

Before generating the use table for each county, it is necessary to compress the various "final demand" categories from the national input-output table into a single column for each industry, ordinarily categorized as final demanders (that is, employed labor, unemployed labor, investors, federal government, state and local government, residential speculators, and non-residential speculators). For example, the use table recognizes twelve different federal government final demand columns for households; these twelve columns are summed to produce a single use column for federal government. The composition of the original columns is set aside, but preserved, should the model user wish to use this information to alter the composition of the use vector for the particular industry. Once this is done, allocation of the demand for "producer commodities," that subset of commodities produced by industries in the traditional input-output framework, among all of the various industries is a relatively straightforward affair. Demand for each producer commodity is allocated to each industry in each region, according to the industry's share of total national demand for the commodity (dictated by the national input-output table) times the region's share of national output in that industry. The assumption implied by this calculation is, as described earlier, that each firm production function is identical with respect to the commodity share of total output, and also that each firm is identical with respect to the labor share of total output. Note that we are applying this principle to our land commodity, as well. The fact that the demand for land will not be collocated with the supply, and that the land commodity cannot be shipped, will produced a fundamental dispersion force in our behavioral equations described in chapter 6.

Demand for the employed labor commodity is allocated to the various industries and regions in much the same way as the producer commodities; demand for employed labor is allocated to each industry, in each region, according to the industry's share of total national demand for employed labor times the region's share of national output in that industry. Once again, this calculation assumes that the labor share of output is the same for all firms in a given industry.

Receipts by the federal government are divided into four broad categories in the National Income and Product Accounts: personal income tax receipts, corporate profit tax receipts, indirect business taxes, and employer and employee contributions to social insurance. Finally, there is the other component of federal government expenditures, federal government borrowing, which must be allocated as well. While these do represent separate and distinct income streams for the federal government, so far as this model is concerned, they all simply represent purchases of a federal government good. However, the four different types of revenue streams do allow us a greater degree of specificity in allocating the output among industries and counties. The indirect business taxes component of demand for the federal government commodity is allocated to each industry in each region according to the industry's share of total national indirect business taxes times the region's share of national output in that industry. The corporate taxes component of demand for the federal government commodity is allocated to each industry in each region according to the industry's share of total corporate taxes times the region's share of national output in that industry. The personal taxes component of demand for the federal government commodity is allocated to each industry in each region according to the industry's share of total labor income plus dividends, interest and rent (both reported in the REIS data series), times the region's share of national output in that industry. Employer and employee contributions to social insurance are allocated to the employed labor industry in each region according to the region's share of national output in that industry. Finally, the total amount of deficit-funded output of the federal government commodity is allocated to the regions and industries in proportion to each industry's/region's share of total federal government demand allocated already, through the various revenue streams. Once allocated, each of these separate federal tax line items may be compressed to a single commodity, "federal government." It is critical to note that under these allocation rules, as we shall see more clearly in the behavioral equations of the model, every industry pays in federal taxes precisely what it gets in federal government commodities. This certainly need not be the case; it could be that some of these industries get far more than they pay for, while others might get far less than they pay for, or perhaps all federal government activity is a dead weight loss and every dollar paid is a dollar down the drain. Because this model is primarily concerned with the dynamics of regional economies within the U.S. and will be taking aggregate US industry growth as essentially exogenous, these questions are not directly relevant; it is enough to know that a given firm, within any given industry, cannot gain any relative advantage, vis-à-vis the cost of federal government services simply by moving from one region within the United States to another region within the United States. That said, the model does allow that there might be some advantage to be gained, by every producer, by locating proximate to a region that produces the federal government commodity, since proximity will effectively lower the cost of "taking delivery" of the federal government commodity. For example, a lobbyist firm of a given size would pay the same amount for federal government services regardless of location, but one locating in Washington, DC might experience a lower delivered cost of the federal government services.

The demand for the "state government" and "local government" commodities will be allocated in quite a different manner from the federal government commodity, to reflect a very different set of assumptions regarding its role in the regional distribution of industry output within the United States. Total receipts by state and local government are divided into the same four broad categories as federal government receipts in the National Income and Product Accounts – personal income tax receipts, corporate profit tax receipts, indirect business taxes, and employer and employee contributions to social insurance, in addition to the total state government deficit/surplus. This total amount of the "state government" and the "local government" commodity output is then allocated to the states in proportion to the state's share of total state and local government expenditures, respectively, from the Bureau of the Census state government revenue series. The state totals for the local government commodity are then further allocated to the counties according to each county's share of the state's total local government expenditures from the Census of Governments. Once the total local government commodity demand is allocated to the various regions, the state and local government demands are allocated among the individual industries according to each industry's share of total regional output. However, in keeping with the working hypothesis that all industries have identical production functions, we shall use these estimates to calculate the weighted national average local government commodity use as a share of output for each industry, and use this ratio to calculate state and local government commodity demand for each industry in each region. Under these allocation rules, an industry may be “buying” far more state and local government services than they are using, or using far more government services than they are buying. The estimated use of local government services has everything to do with the average provision level of local government commodities where the industry is located, and nothing to do with the amount of local government taxes that the industry is paying in any given region. This is in keeping with the presumed public good nature of the state and local government goods, and will open up the potential, as we shall see in the chapter describing the behavioral equations, that industries might face much higher or lower prices for the local government good depending on where they are located in the United States. These price differences across regions will in part drive regional development patterns, while the assumed entry of the state and local government good commodity into the production function seems an improvement over either assuming that the local government commodity does not enter into any production function, or that “what you pay for is what you get” in the state and local government commodities.

The demand for the “transfer payments” commodity are allocated from the total transfer payments reported by NIPA, to the counties, according to the counties’ share of state government, which reflects the fact that state governments generally administer transfer payment programs and determine the level of transfer provision. Effectively, this will mean that unemployed labor will, potentially, be able to gain additional transfer payments through migration between regions in the United States; the returns from transfer payments for the “unemployed labor” industry will differ among regions both because of different provision levels among states, and because of differences in delivered prices within each state. It is expected that the response of unemployed labor to these signals will be weak, but might be present when the model is estimated.

Recall the two physical capital commodities in our merged IO-SAM – residential physical capital and non-residential physical capital. The aggregate demand for residential physical capital and for non-residential physical capital is calculated using precisely the scheme used to allocate the supply of these industries, using our required capital stock metrics. As we shall see, this will have the effect of generating no interregional trade in capital.

The demand for financial capital comes only from the residential speculator industry and the nonresidential speculator industry, and is allocated among regions according to each region's share of total output in the two speculator industries.

In this incarnation of the model, there are a total of four commodities that are to remain strictly exogenous. These are international exports, international imports, intertemporal exports, and intertemporal imports. The two import commodities are, in essence, used but not made, and the two export commodities are made, but not used.

International imports are given by industry in the U.S. input-output use table, and are scaled to match NIPA U.S. total imports. The total imports are allocated to all industries in all regions in the usual way, in proportion to the region's share of U.S. output in each of the importing industries. International exports are given by industry in the U.S. input-output make table, and are scaled to match NIPA U.S. total exports. Exports, likewise, are allocated to all industries in all regions in proportion to the region's share of U.S. output in each of the importing industries. This allocation implies that all firms in a given industry produce the same share of output for export, which in gravity model terms implies that all international markets are the same effective distance from all U.S. regions. This is the same as saying that international transportation of the commodity is so much more expensive then domestic shipping of the commodity, that it renders U.S. internal distances irrelevant for purposes of international trade.

Intertemporal imports and exports are conceptually similar to international exports and imports. These are commodities produced in an earlier time period to be consumed in this time period (intertemporal imports). Similarly, they can be produced in this time period to be consumed in another time period (intertemporal exports). Intertemporal imports will appear as a commodity in the use table and intertemporal exports will appear in the make table. In the NIPA accounts, intertemporal imports will show up as a negative dollar amount of industry inventories for producer commodities, and as a negative dollar amount of savings for financial commodities. For each of these categories, intertemporal imports are allocated to the appropriate industries and regions according to their share of total output. Likewise, intertemporal exports will show up in the NIPA accounts as a positive dollar amount of industry inventories, and as a positive dollar amount of savings. For each of these categories, intertemporal exports are allocated to the appropriate industries and regions according to their share of total output. For our purposes, we need only worry about the net intertemporal exports or imports, so for any given industry, for any given year, there will only be a nonzero intertemporal export or a nonzero intertemporal import, but never both. Exploring endogenous intertemporal imports and exports (a rational expectations model) is one potentially interesting line of future research.

At this point, we have developed a data set for a complete merged IO-SAM for every county in the United States. In the next chapter, we will develop a complete set of domestic trade flow data, which will give us all of the information needed to build our new economic geography model in chapters 5 and 6.

Chapter 4

Estimation of the Trade Relationships in the Model – The Immaculate Conception of Trade

Why Estimate Interregional Trade Flows?

Based upon the data structure developed in chapters 2 and 3, we now have all of the data required to estimate elasticities of substitution for all commodities in the model and to estimate a complete set of county-to-county trade flows for the United States; this is the goal of this chapter.

Estimation of interregional and intraregional trade flows is a critical step in much current work in regional, urban, and international economics; these trade flows are essential to understanding how money flows within and between regions, and hence how exogenous shocks in one region, can translate into impacts in other regions. Isard et. al. (1960) observed that just as regional data on employment, income, industrial production, and population provide useful information on the level of economic activity in a region, information on the movements of goods and services between regions provides critical information on the strategic economic interrelationships between regions. According to Miller and Blair (1985), such interregional trade flows are also a critical component needed in any input-output models, particularly those comprised of more than one region.

The Empirical Challenge to Estimating Interregional Trade Flows

To date, all theoretical and applied models of trade flows have been estimated using an explicit set of trade flow data for calibration. This has been a serious limiting factor in the actual empirical estimation and application of these models, particularly in domestic trade situations, where trade data can be difficult or impossible to come by. In this chapter, we describe and apply an alternative approach to estimation of elasticities of substitution, transportation costs, and trade flows. While our specific application will use a gravity model derived from a Dixit-Stiglitz production function, the estimation technique could be applied to a broad range of theoretical trade models; in particular, the approach outlined here could be applied to any specification of the gravity model. The approach is unique, in that it requires no explicit knowledge of trade flows for calibration. Instead, it relies on panel data of output and demand by region to determine the nature and magnitude of the gravitational forces at work.

We have mentioned the difficulty of obtaining data on domestic interregional commodity flows in most countries. In the United States, for example, the only comprehensive data set currently available is the Commodity Flow Survey (CFS), conducted once every five years by the Bureau of the Census, with funding and technical support provided by the Bureau of Transportation Statistics. The 1997 Commodity Flow Survey marked the most comprehensive effort since 1977 to identify where and how goods are shipped in the United States. Nevertheless, there are serious problems inherent in this data set, when applied to the problem at hand. First, the data set records all shipments by origin and destination, without regard for whether the shipment represents a transaction, or whether the shipment represents delivery of the commodity from the supplier to the buyer, or some intermediate step. Secondly, the Commodity Flow Survey only provides trade data between states in the United States. Third, and perhaps most critical, the CFS only records shipments of manufactured goods and not interregional transfers of non-manufactured goods.

Traditional Methods of Estimating Interregional Trade Flows

Thus, in the absence of specific survey data, it has traditionally been necessary to rely on incomplete survey data and/or non-survey estimation techniques. Some of the most frequently applied techniques include location quotient techniques, commodity balance technique, Moses technique (Moses, 1968), Tiebout method (Tiebout, 1962), and numerous formulations of the gravity model.

The location quotient technique is certainly the most widely used “back of the envelope” method for estimating trade flows. This method involves using some measure of a region’s import or export orientation vis-à-vis a specific commodity. Generally, the region is considered an exporter if the ratio of regional employment in the industry in question to total regional employment exceeds the same ratio for the country as a whole; otherwise, it is considered an importer. If a region is an exporter, then it is assumed that all local demand for the commodity is met by local suppliers, so there are no imports of the commodity. Likewise, an importer region is assumed to export none of the commodity in question, so all local production is consumed locally, and the balance is imported from the closest exporter. A simple location quotient methodology was used by Nevi, Roe, and Round (1966) to estimate a two region model of the United Kingdom, and by Vanwynsberghe (1976) to construct a three region model of Belgium. In a series of papers by Round (1972, 1978a, 1978b, 1983) a wide variety of these non-survey techniques are explored in a multiregional setting. While the location quotient method is simple to understand and to estimate, it is fundamentally flawed by the assumption that all demand for a commodity will be met by the closest available supplier. Because of this, the phenomenon of cross-hauling cannot be explained, though it is clearly ubiquitous in regional economies. Also, this method must inevitably overstate the degree of trade within a region, and will underestimate the extent of interregional trade, as explored by Harrigan et al. (1981), Schaffer and Cu (1969) and Morrison and Smith (1974).

Gravity models have been ubiquitous in the empirical modeling of spatial interaction and human behavior since the early 1940’s (Sen & Smith, 1995). Gravity models demonstrate such a high degree of explanatory power in modeling trade flows, virtually every theoretical model of trade must demonstrate compatibility with some gravity model specification. Versions of gravity model formulations have been proposed specifically to estimate commodity flows between regional economies (Miller & Blair, 1985). The basic gravity hypothesis is that the amount of a particular commodity traded from one region to another is directly related to output of the exporting region and to the level of demand in the importing region, and is inversely related to the relative distance between the two regions, as compared to the distance to all other potential trading partners. The application of gravity models to estimation of interregional trade flows was suggested by Leontief and Stout (1963) and was first explored by Thiel (1967). Polenske (1970a) used a gravity estimation technique to calculate Japanese interregional trade data, and subsequently (1970b), demonstrated that gravity estimates of interregional trade and estimates from an explicit multiregional input-output model were about equally good. Estimates of interregional trade based on gravity model formulations have also been made by Urib et al. (1966), Gordon (1976), and Black (1972), among others. Such gravity models allow for the possibility of cross hauling, there is no obvious reason to believe they will generate biased results, and their accuracy has repeatedly been supported by the data. The major downfall of gravity models, to this point, has been that they require a complete set of trade flow data to be estimated, and with the exception of international trade, quality data of this sort is rarely available.

In estimating trade flows for our regional model of the United States economy, we will estimate a formulation of the gravity equation based upon a Dixit-Stiglitz production function. This specification we develop will require no explicit trade flow data, yet allows one to estimate a complete and balanced set of commodity trade flows, and also allows for ubiquitous cross hauling.

Justification for Applying a NEG Formulation of the Gravity Model

While there are many alternative theories of trade that are consistent with various incarnations of the gravity model, and while any of these could be estimated using the basic procedure outlined in this chapter, the theoretical framework used in this chapter will draw upon the same production function used by Fujita, Krugman, and Venables (1999), and many others in the new economic geography literature. The Dixit-Stiglitz production function, in fact, has been identified by Krugman (1991) as one of the three cornerstones of new economic geography. This formulation was selected over other alternatives for several reasons that will be outlined in detail in the following chapter. Briefly, the Dixit-Stiglitz production function is theoretically consistent with "second nature" agglomerations of economic activity that is the cornerstone of new economic geography; that is, agglomeration that has taken place by the self-reinforcing mechanism of increasing returns to trade brought about by agglomeration. Because this agglomeration could hypothetically happen in any number of places, the agglomeration is driven by historic "accident" and historesis. In addition, the formulation we will estimate also allows for "first nature" differences among locations, or those differences in resource base or physical location that can lead to agglomeration that can only take place at a specific location or locations. The estimation procedure will allow estimation of both the first nature and the second nature effects on trade. These second nature agglomerations are particularly appealing in a regional economic framework, where it is otherwise difficult to explain why cities with remarkably similar endowments of non-mobile resources (for example, Las Vegas, Nevada and By, Nevada) should have such remarkably different types and levels of economic activity. Because the Dixit-Stiglitz formulation will fundamentally reinforce histeresis in economic activity, it is an appealing mechanism for explaining the persistence of regional economic agglomerations in light of the relative mobility of the many factors that compose these economic agglomerations.

Deriving the Gravity Model from a Dixit-Stiglitz Production Function

Consider a simple two region economy with transportation costs. In this most basic specification, we can specify the region 1 price index for a single manufactured good as:

$$P_1^{1??} \; ? \; n_1 p_1^{1??} \; ? \; n_2 ? p_2 T ?^{1??} \qquad (4.1)$$

where P_1 is the price index for region 1, $?$ is the elasticity of substitution between varieties of the manufactured good, n_1 is the number of domestic varieties of the manufactured good (sold at price

p_1) and n_2 is the number of varieties imported from region 2, at a price of p_2T, as dictated by an iceberg transportation assumption ($T ? 1$).

The demand for any specific variety of the manufactured good is driven by a CES subutility function (from Dixit-Stiglitz, the backbone production/indirect utility function in the model), we know that the demand in region 1 for varieties of the manufactured commodity produced in region 2, is given by:

$$D_{n_2 1} ? \frac{n_2 ?p_2 T ?^{??}}{P_1^{1??}} ?D_1 ? \frac{n_2 ?p_2 T ?^{1??}}{n_1 p_1^{1??} ? n_2 ?p_2 T ?^{1??}} ?D_1 \qquad (4.2)$$

where $D_{n_2 1}$ is the demand in region 1 for varieties of the manufactured good produced in region. Similarly, we know that the demand in region 1 for varieties of the manufactured commodity produced in region 1 is given by:

$$D_{n_1 1} ? \frac{n_1 p^{1??}}{P_1^{1??}} ?D_1 ? \frac{n_1 p^{1??}}{n_1 p_1^{1??} ? n_2 ?p_2 T ?^{??}} ?D_1 \qquad (4.3)$$

Note that equations (4.2) and (4.3) describe a simple gravity model, in that the level of trade is a function of the transportation cost T between the two regions and the elasticity of substitution $?$.

Deriving the Gravity Model from Our Expanded NEG Model

Regardless of the entity in question, in our model all will face a Dixit-Stiglitx (constant elasticity of substitution nested Cobb-Douglas) production function of the form:

$$\overset{G}{\underset{g?1}{?}} ?\tilde{g}_{gmirt} ?^{?_{\tilde{g}it}} ? E_{it} ? q_{mirt} \qquad (4.4)$$

for manufacturer m, belonging to industry i, located in region r, at time t. G represents the total number of goods in the economy . $\tilde{g}_{gmirt}$ is the quantity of composite commodity good $\tilde{g}$ used by manufacturer m, in industry i, in region r, at time t. $?_{\tilde{g}it}$ is the share of composite commodity good $\tilde{g}$ used in industry i at time t. Note that the production function, at any point in time, is industry and time specific, but not region or manufacturer specific. E_{it} is the fixed cost of production for industry i at time t. Finally, q_{mirt} is the total output of manufacturer m, in industry i, in region r, at time t.

This behavioral equation will apply to all manufacturers, regardless of the "type" of entity in the traditional sense. For example, a labor manufacturer will use a mix of inputs to produce a labor commodity for sale to those manufacturers who demand such commodities. Implicitly, this amounts to the traditional cost minimization exercise for households and other "final demanders," but that distinction is artificial for purposes of this model.

Regardless, again, of the entity in question, every manufacturer also faces the traditional constant returns to scale Cobb-Douglas budget share constraint given by

$$\sum_{g=1}^{G} ?_{git} = 1 \qquad (4.5)$$

As we shall see in the next chapter, this is consistent with agglomeration economies in the new economic geography framework, which are based on increasing returns at the industry level, but not at the firm level.

Because we wish to allow for the possibility of joint production, as implied by our data structure described earlier, we must devise a mechanism for translating between industry production and commodity production. To that end, we specify:

$$q_{mirt} = \sum_{g=1}^{G} ?_{git} q_{mirt} \qquad (4.6)$$

where

$$\sum_{g=1}^{G} ?_{git} = 1 \qquad (4.7)$$

where $?_{git}$ is the output share of good g in industry i, at time t. For joint production, we shall calculate the U.S. average inputs for commodity g at time t, given by:

$$?_{\tilde{g}gt} ? \sum_{i?1}^{I} \left(?_{\tilde{g}it} \frac{Q_{git}}{\sum_{i?1}^{I} Q_{git}} \right) \quad (4.8)$$

where $?_{\tilde{g}gt}$ is the input share of commodity $\tilde{g}$ used in the production of commodity g at time t, and I is the total number of industries. To simplify the process of calculating prices across all regions and commodities in the model, we shall use these input shares in all price and trade calculations. Industries will only reenter the equation when we allow for industry expansion/contraction in a region in response to price changes in the various commodities across regions.

Despite the greater complexity of this specification, the gravity model will remain largely recognizable. Instead of iceberg transportation costs, we shall explicitly calculate shipping costs such that the delivered price of a commodity is given by:

$$P_{g\tilde{r}rt} ? P_{g\tilde{r}t} ? \sum_{\tilde{?}?1}^{?} ?_{g?t} d_{?\tilde{r}rt} ?^{?gt} \quad (4.9)$$

where $P_{g\tilde{r}rt}$ is the delivered profit-maximizing price in region r of commodity g, produced in region $\tilde{r}$, at time t, and $P_{g\tilde{r}t}$ represents the EXW (Ex Works, or the price at the factory door) profit-maximizing price for commodity g, manufactured in region $\tilde{r}$, at time t. $?$ is the number of modes of transportation, $d_{?\tilde{r}rt}$ represents the distance from region $\tilde{r}$ to region r, by mode $?$, at time t, $?_{?gt}$ is the share of transportation commodities $?$ used in shipping commodity g at time t, and $?_{g?t}$ represents the unit distance cost of shipping commodity g, by mode $?$, at time t.

Under this formulation of prices, and with the CES assumption of Dixit-Stiglitz, we may specify a trade relationship for every commodity-county-county combination. For any given commodity, the level of trade between any two regions, r and $\tilde{r}$, is:

$$T_{g\tilde{r}rt} = \frac{Q_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\sigma_g}}{\left(\sum_{\tilde{r}=1}^{R} Q_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\sigma_g} \right)} \cdot D_{grt} \qquad (4.10)$$

where $Q_{g\tilde{r}t}$ is the aggregate amount of commodity g, produced in region $\tilde{r}$, at time t, and D_{grt} is the aggregate demand for commodity g, in region r, at time t. Note that this is nothing more than a specification of equations (4.2) and (4.3), expanded to encompass any number of regions and commodities and shedding the restrictive iceberg price assumption.

Introducing Supply and Demand Constraints into the Model

The gravity model specified above is, by design, demand constrained. If we sum across all supplier regions $\tilde{r}$, we discover that

$$\sum_{\tilde{r}=1}^{R} T_{g\tilde{r}rt} = \sum_{\tilde{r}=1}^{R} \left[\frac{Q_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\sigma_g}}{\left(\sum_{\tilde{r}=1}^{R} Q_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\sigma_g} \right)} \cdot D_{grt} \right] \Rightarrow \sum_{\tilde{r}=1}^{R} T_{g\tilde{r}rt} = D_{grt} \; \forall \; g,r,t \qquad (4.11)$$

That is, the total trade in commodity g from all regions, terminating in region r, is equal to the total demand for good g, in region r, an accounting condition that must be true by definition.

However, while theoretically complete, accurate empirical estimation of the above model requires one additional step, the addition of an explicit supply constraint to insure that every region in the model sells all output,

$$\sum_{r=1}^{R} T_{g\tilde{r}rt} = Q_{g\tilde{r}t} \; \forall \; g,\tilde{r},t \qquad (4.12)$$

If the model captured all trade perfectly, this would not be a concern, but in the presence of error in the estimation, we must transform equation (4.11) into a classic, doubly constrained gravity model following the form developed by Wilson (1967, 1970, 1974):

$$T_{g\tilde{r}rt} \; ? \; \frac{Q_{g\tilde{r}t}\left(P_{g\tilde{r}t} \; ? \sum_{\tilde{?}=1}^{?} ?_{g?t}\, d_{?\tilde{r}rt}^{\;?_{?gt}}\right)^{??_{g}}}{\sum_{\tilde{r}=1}^{R}\left[Q_{g\tilde{r}t}\left(P_{g\tilde{r}t} \; ? \sum_{\tilde{?}=1}^{?} ?_{g?t}\, d_{?\tilde{r}rt}^{\;?_{?gt}}\right)^{??_{g}}\right]} \; ? D_{grt} \quad (4.13)$$

$$P_{g\tilde{r}t}^{\;??_{g}} \; ? \left[\sum_{r=1}^{R} D_{grt}\left(B_{grt} \; ? \sum_{\tilde{?}=1}^{?} ?_{g?t}\, d_{?\tilde{r}rt}^{\;?_{?gt}}\right)^{??_{g}}\right]^{?1} \quad (4.14)$$

$$B_{grt}^{\;??_{g}} \; ? \left[\sum_{\tilde{r}=1}^{R} Q_{g\tilde{r}t}\left(P_{g\tilde{r}t} \; ? \sum_{\tilde{?}=1}^{?} ?_{g?t}\, d_{?\tilde{r}rt}^{\;?_{?gt}}\right)^{??_{g}}\right]^{?1} \quad (4.15)$$

where $P_{g\tilde{r}rt}$ is the profit maximizing price in region r of commodity g, produced in region $\tilde{r}$, at time t, which will drive the distance decay function in the gravity model. B_{grt} is a balancing factor that insures that all output is sold in all regions in the model; that is, that equation (4.12) is satisfied.

The balancing factors in this configuration serve to capture, in some sense, the "first nature" differences among various regions in the model; that is, differences in buying and selling prices that have nothing to do with the relative locations of buyers and sellers. In estimating the model, $P_{g\tilde{r}t}$ can be viewed as the EXW price as calculated based upon the behavior of the demander. That is, given our behavioral assumptions, the demanders of commodity g produced in region $\tilde{r}$ are purchasing at a level consistent with an EXW price of $P_{g\tilde{r}t}$. B_{grt}, on the other hand, can be interpreted as the EXW price estimated based upon the behavior of the producer; given the demand and transportation costs to their markets in all regions r, the producers of commodity g are producing at a level consistent with an EXW price of B_{grt}. If estimation of the model were subject to no statistical error whatsoever, then we would find (Wilson, 1970) that

$$P_{g\tilde{r}t} \; ? \; B_{g\tilde{r}t} ? \; g,\tilde{r},t \qquad (4.16)$$

Of course, since the estimation is clearly going to be subject to statistical error, these two values will not be equal and both, as it turns out, will have to be estimated.

Relaxing the Iceberg Price Assumption in the Model

Ordinarily, the distance decay function of a gravity model includes only the straight line distance between regions, as a proxy for the "economic distance" between regions. However, in this model, we shall take advantage of an additional data source, and use explicit transportation infrastructure data to populate equation (4.9). The unique data source that will be used is an Oak Ridge National Labs database that estimates the "degree of difficulty" or impedance, of moving between two counties via the transportation mode(s) in question. A complete description of the Oak Ridge National Labs impedance database is provided in appendix C.

Note also, that this makes one other important departure from the classic iceberg pricing mechanism, in that transportation costs are assumed to be independent of, rather than proportional to, the EXW price P_{grt}. The classic iceberg shipping cost function implies that a 10% increase in manufacturing cost will necessarily imply a 10% increase in shipping costs. This mechanism seems quite unreasonable for purpose of this analysis, particularly in light of the fact that transportation infrastructure is so explicitly modeled. Therefore, shipping costs are designed to enter explicitly into the delivered price.

Several parameter estimation methods for gravity models have been explored in the statistics literature; maximum likelihood, linear least squares, and non-linear least squares have been the most common approaches (Sen & Smith 1995). However, all of the methods used to this point have required knowledge of the set of trade flows $T_{g\tilde{r}rt}$ for estimation. To circumvent the problem of inadequate data, and to introduce basic dynamics into the model, we will rely upon the equations (4.13), (4.14), (4.15). Under the doubly constrained gravity equations, the supply and demand trade flow identities of (4.11) and (4.12) hold for all time periods as well. The output identity (4.12), lagged one time period becomes:

$$Q_{g\tilde{r}t-1} = \sum_{r=1}^{R} T_{g\tilde{r}rt-1} \tag{4.17}$$

and first differencing the total output equation, we get:

$$\Delta Q_{g\tilde{r}t} = Q_{g\tilde{r}t} - Q_{g\tilde{r}t-1} = \sum_{r=1}^{R} T_{g\tilde{r}rt} - \sum_{r=1}^{R} T_{g\tilde{r}rt-1} \tag{4.18}$$

We are ultimately interested in how a change in demand can predict the change in output, all other things being equal. To this end, we will define

$$T_{g\tilde{r}rt-1} = \frac{Q_{g\tilde{r}t-1}\cdot\left(P_{g\tilde{r}rt-1}\right)^{-\sigma_g}}{\sum_{\tilde{r}=1}^{R}\left[Q_{g\tilde{r}t-1}\cdot\left(P_{g\tilde{r}rt-1}\right)^{-\sigma_g}\right]}\cdot D_{grt-1} \tag{4.19}$$

using the first difference equation, in conjunction with the trade flow equations and the trade summation conditions for t and $t-1$, and adding the simplifying assumption that

$$B_{grt} = B_{grt-1} \tag{4.20}$$

we can derive the relationship

$$\frac{Q_{g\tilde{r}t}}{Q_{g\tilde{r}t-1}} = \frac{\sum_{r=1}^{R} D_{grt}\cdot\left[B_{grt}\cdot\sum_{\tilde{r}=1}^{R} d_{\tilde{r}rt}^{-\sigma_{gt}}\right]^{-\sigma_g}}{\sum_{r=1}^{R} D_{grt-1}\cdot\left[B_{grt}\cdot\sum_{\tilde{r}=1}^{R} d_{\tilde{r}rt-1}^{-\sigma_{gt-1}}\right]^{-\sigma_g}} \tag{4.21}$$

The model in equation (4.21) reflects the change in output in a given region as a function of the change in demand in the various markets being served, weighted by the price that would be charged in those markets. Recall that B_{grt} is the balancing factor that insures all demand is satisfied in all regions in the model, and that embedded in this balancing factor is $P_{g\tilde{r}t}$, the balancing factor that ensures all output of every region is sold.

The estimation process involves iterative estimation of the SSE minimizing set of $?_g$, $P_{g\tilde{r}t}$ and B_{grt} values, for each commodity in the model. This task is made particularly challenging, since the set of $P_{g\tilde{r}t}$ and B_{grt} values for each commodity are defined by nonlinear equations, these values are themselves estimated in an iterative procedure nested within the estimation of $?_g$ (Fotheringham & O'Kelly, 1989, Cesario, 1974).

Data Used in the Model Estimation

Estimation of the gravity model we have outlined requires, for any given commodity, data on total output by region Q_{grt} and total demand by region D_{grt}. Estimation also requires a comprehensive set of relative transportation cost data between each pair of regions for each mode of transportation; that is, a value of $d_{?\tilde{r}rt}$ for each transportation commodity $?$, for every origin region $\tilde{r}$ and destination region r, for each time period t. Finally, we require an estimate of the budget shares devoted to each of the transportation modes for each commodity $?_{?gt}$.

The model is theoretically applicable to any set of regions and commodities; for our purposes, the model will be estimated for a 3110 region model of the United States, composed of all counties, parishes (Louisiana), statistical areas (Alaska), and independent cities (Virginia) in the United States, for each of the 517 commodity categories identified in the merged IO SAM tables developed in chapters 2 and 3. All required data can be constructed at the county level, in the United States, as described in chapters 2 and 3; we explicitly include all counties in estimating the model so the fine level of geographic detail increases confidence in estimated $?_g$ values, particularly for those commodities sold primarily within very local markets. Estimated trade flows in the model can then be "rolled up" to estimates of interstate trade flows, which may be compared against the Commodity Flow Survey for illustrative purposes. Estimated trade flows in the employed labor industry may also be compared to the 2000 decennial census commuter flow data, as well as the REIS net residence adjustment data.

The procedures used to calculate a comprehensive and internally consistent set of supply and demand data for all commodities, for all counties in the United States, has been described in chapter 3, and need not be repeated here. However, the data and procedures used to estimate transportation costs bare close examination before proceeding further.

To more accurately measure the transportation component of the model, data on impedance between regions were extracted from Oak Ridge National Laboratories' (ORNL) Commodity Flow Survey (CFS) multi-modal network. The CFS multi-modal network was constructed to simulate routes taken by freight shipments in the 1997 Bureau of Economic Analysis Commodity Flow Survey, for the purpose of testing all Commodity Flow Survey responses for reasonableness and consistency. However, the database is adaptable for addressing a number of other transportation issues, and is particularly well adapted to multimodal transportation infrastructure issues, like those faced in this research. The database is designed to estimate the total impedance (or relative difficulty) of moving along any given route, using any given transportation mode or combination of modes, from any given point to any other given point. The measure of impedance across all modes is normalized such that one mile of rural four lane interstate highway has an impedance of one, with all other transportation options measured by that standard. Intermodal comparisons are generally quite problematic, but for this model any intermodal differences cancel out, so accurate analysis relies only upon impedance numbers that are comparable within a transportation mode, and need not be comparable across modes. Our estimation procedure will account for commodity by commodity differences in transportation costs by mode, as well as commodity by commodity differences in intensity of mode usage, as we shall see. A complete description of the ORNL data is available in appendix C.

This database was used to identify, for each of the redefined transportation modes (highway, rail, water, air and pipeline) the lowest impedance for every combination of counties, from population centroid to population centroid. Note that every transportation mode allows for explicitly different impedances going either way along a given route, so the impedance from county $\tilde{r}$ to county r, by any given mode, need not be the same as the impedance from county r to county $\tilde{r}$ by the same mode along the same route. This is especially true for the waterway impedance numbers. Internal impedance from every county to itself was also estimated for each mode, based upon the average impedance between every combination of traffic generators in the county.

At this point, the county to county impedance is known for every combination of origin and destination counties for each of the five modes. The database is now missing a significant number of linkages because one or more transportation modes are absent for various county-county combinations. For those missing county-county-mode linkages in the database, the missing value was assumed to be the equivalent of thrice the largest observed county-county-mode impedance value for all observed modes for that observed county-county pair. Sensitivity analysis revealed that results were very robust to changes in this assumption, and that all modes were statistically significant to several commodities.

Once these impedance numbers are generated, they are assigned to the individual transportation commodities identified by our merged IO/SAM, and presumed to be involved in the shipment of goods and services. The transportation commodities identified in the merged IO/SAM are air transportation, which is assigned the air impedance number, rail transportation, which is assigned the rail impedance number, water transportation, which is assigned the water transportation number, and truck transportation, and ground passenger transportation, which are all assigned the highway impedance number. There remains one mode of commodity shipment, pipeline transportation, for which no good transportation impedance data is available; pipeline shipping is excluded from the census of transportation, and hence is not available in the multimodal database. As such, straight line distance from population centroid to population centroid is used as a proxy for the pipeline transportation commodity.

Now that we have specified a complete merged IO/SAM framework, and we have generated a complete set of county by county by transportation mode impedance data set, let us return to our trade flow equation (4.21) and outline the known parameters and those parameters that will be estimated:

$$\frac{Q_{g\tilde{r}t}}{Q_{g\tilde{r}t?1}} ? \frac{\sum_{r?1}^{R} D_{grt} ?\left(B_{grt} ?\prod_{??1}^{?} d_{?\tilde{r}rt}^{\,?_{?gt}} \right)^{??g}}{\sum_{r?1}^{R} D_{grt?1} \left(B_{grt} ?\prod_{??1}^{?} d_{?\tilde{r}rt?1}^{\,?_{?gt?1}} \right)^{??g}} \qquad (4.22)$$

The quantities supplied, $Q_{g\tilde{r}t}$ and $Q_{g\tilde{r}t?1}$, and the quantities demanded, D_{grt}, and $D_{grt?1}$, can be extracted for every county from the merged IO/SAM table developed in chapter 3. Recall that $?_{g?it}$ and $?_{g\tilde{?}t}$ are the Cobb-Douglas budget shares devoted to purchase of transportation modes $?$ and $\tilde{?}$ in time t, respectively, for shipment of commodity g, and $?_{g?t?1}$ and $?_{g\tilde{?}t?1}$ are the Cobb-Douglas budget shares devoted to purchase of transportation in time $t?1$. These values, too, are estimated from the merged IO/SAM data. From the IO/SAM data, we know the budget share of each industry devoted to the purchase of each transportation mode, but not directly the share of each transportation mode devoted to the shipment of each commodity. The estimated share of each transportation mode devoted to the shipment of each commodity will be calculated as:

$$?_{?gt} ? \sum_{i?1}^{I} \left(?_{?it} \frac{Q_{git}}{\sum_{i?1}^{I} Q_{git}} \right) \qquad (4.23)$$

That is, the budget share of commodity g, that is devoted to transportation mode $?$, is estimated as the average of each industry's budget share devoted to transportation mode $?$, weighted by the industry's total share of the output of commodity g.

The distance variables $d_{\tilde{?}\tilde{r}rt}$, $d_{?\tilde{r}rt}$, $d_{?\tilde{r}rt?1}$, and $d_{?\tilde{r}rt?1}$ are normally proxied by some straight-line distance measure, so:

$$d_{\tilde{?}\tilde{r}rt} ? d_{?\tilde{r}rt} ? d_{\tilde{?}\tilde{r}rt?1} ? d_{?\tilde{r}rt?1} ? d_{\tilde{?}r\tilde{r}t} ? d_{?r\tilde{r}t} ? d_{\tilde{?}r\tilde{r}t?1} ? d_{?r\tilde{r}t?1} \qquad (4.24)$$

However, we will be using our Oak Ridge transportation impedance measures instead of simple straight-line distance. These impedance measures do not change over time, as they are estimated from a single year's worth of impedance information (1997), but impedance between two regions can differ, both with the mode and the direction of travel. So, for this analysis,

$$d_{?\tilde{r}rt} ? d_{?r\tilde{r}t?1} \qquad (4.25)$$

As additional years of transportation data become available, impedances could be expanded to change over time, as well.

The Model Estimation Procedure

This leaves the factors that will be estimated in the analysis. All EXW price related variables $P_{g\tilde{r}t}$ and B_{grt} are initially set to 1, equivalent to an assumption of no first nature differences between regions and no differences in intermediate input prices between regions. When these balancing factors are ultimately estimated, they will subsume not only any first nature and production cost differences, they will also absorb the entire error term $?_{g\tilde{r}t}$. Hence, we have no real means to determine the statistical goodness of fit in the results portion of this chapter, and must rely upon comparison to limited shipping data and the intuitive reasonableness of the results to judge our success.

Given the functional form of equation (4.21) and the assumptions given by equations (4.23) and (4.25), estimates of $?_g$ are calculated for each commodity g, using non-linear least squares. The estimation is made using data for all 3,110 regions in the U.S. database for the years 1999-2001.

Once $?_g$ have converged, we have effectively estimated the elasticities of substitution and transportation costs for each commodity in the model, subject to our initial condition that $P_{g\tilde{r}t}$ and B_{grt} are 1. These EXW balancing factors $P_{g\tilde{r}t}$ and B_{grt} are solved iteratively (of necessity, since they enter into the trade flow calculations nonlinearly), and the iterative estimation of $P_{g\tilde{r}t}$ and B_{grt} is followed by reestimation of $?_g$. Once again, the iterative procedure must ultimately converge to a unique set of values (Andersson, 1981), and it is empirically observed that the further the values of the $P_{g\tilde{r}t}$ and B_{grt} from their initial estimated values of one, the greater the number of iterations required to achieve convergence. This paper represents the first time a doubly constrained gravity model, with this level of geographic and commodity detail, has been estimated.

Once this procedure is completed, we have produced a complete, internally consistent, set of trade flow relationships for all commodities and all regions in the model. A complete description of key estimated parameters follows.

Results

While we can provide some quantitative evidence pointing to the validity of our model, data, and approach, it should be made clear to the reader that the opportunities to test our elasticities of substitution and trade flow estimates are seriously limited, a problem that has been faced by anyone who makes the effort to parameterize a regional economic model of this sort. The absence of good test data, and the fact that any number of alternative gravity model specifications might fit the data as well or better, means that we must rely as much upon the intuitive logic of the model, as on the statistical testing of the model. That said, everything reported in this section suggests that our model specification works well and fits the data accurately, and that the logic of the model is consistent with the values of all of the parameters that are estimated.

Table 4.1 shows the average estimated elasticity of substitution, $?_g$, for the NAICS commodity categories, upon completion of the iterative procedure used to estimate, $?_g$, $P_{g\tilde{r}t}$, and B_{grt}. The iterative estimation procedure, repeated until all demand, in all regions, is perfectly satisfied and all supply, in all regions, are distributed, means that there simply is no error in the estimation process; the three variables and the estimation process are sufficient to explain the dependent variable with absolutely no error. Ordinarily, one would be able to test the statistical validity of our estimated values, but here we are restrained by the mathematical rigor of the double constraint, but the very accuracy of our procedure means that it cannot be statistically tested. As a result, we are left to simply examine the results to determine if they appear credible, and to rely upon the intuitive appeal of the model structure and the reasonableness of the estimates.

Table 4.1: Estimated $?_g$, values for all commodities.

Commodity	$?_g$	Commodity	$?_g$
Agricultural products	1.6434	Other electrical equipment and component manufacturing	1.8805
Forestry, fishing, hunting, and trapping	2.2046	Motor vehicle manufacturing	1.4226
Logging	2.4256	Motor vehicle body and trailer manufacturing	1.9396
Support activities for agriculture and forestry	3.1715	Motor vehicle parts manufacturing	2.4818
Oil and gas extraction	1.2868	Aerospace product and parts manufacturing	1.9239
Coal mining	1.0384	Railroad rolling stock manufacturing	2.6410
Metal ore mining	1.1844	Ship and boat building	3.1830
Nonmetallic mineral mining and quarrying	2.2053	Other transportation equipment manufacturing	2.2001
Support activities for mining	2.4511	Household and institutional furniture and kitchen cabinet manufacturing	2.0423
Electric power generation, transmission, and distribution	1.7971	Office furniture (including fixtures) manufacturing	2.2844
Natural gas distribution	1.3180	Other furniture related product manufacturing	2.1014
Water, sewage, and other systems	3.0640	Medical equipment and supplies manufacturing	1.9435
Waste management and remediation services	2.2099	Other miscellaneous manufacturing	3.2856

Commodity	$?_g$	Commodity	$?_g$
Construction	3.4309	Wholesale trade	3.3026
Animal food manufacturing	2.1076	Retail trade	5.8448
Grain and oilseed milling	2.0498	Air transportation	2.9869
Sugar and confectionery product manufacturing	1.3919	Rail transportation	2.2040
Fruit and vegetable preserving and specialty food manufacturing	2.1090	Water transportation	2.5460
Dairy product manufacturing	2.5510	Truck transportation and couriers and messengers	3.2881
Animal slaughtering and processing	1.6931	Transit and ground passenger transportation	4.1053
Seafood product preparation and packaging	1.2103	Pipeline transportation	1.9474
Bakeries and tortilla manufacturing	3.0524	Scenic and sightseeing transportation and support activities for transportation	5.3895
Other food manufacturing	2.3944	Postal Service	6.2065
Beverage manufacturing	3.0115	Warehousing and Storage	4.2486
Tobacco manufacturing	1.1536	Newspaper, periodical, book, and directory publishers	4.6908
Fiber, yarn, and thread mills	2.1958	Software publishers	1.8078
Fabric mills	1.3128	Internet services, data processing, and other information services	3.3499
Textile and fabric finishing and fabric coating mills	2.0549	Motion picture and sound recording Industries	2.1920
Textile furnishings mills	1.4970	Radio and television broadcasting	3.3091
Other textile product mills	2.1141	Cable and other subscription programming and program distribution	4.1051
Apparel knitting mills	2.0561	Telecommunications, except cable and other programming distribution	2.3933
Cut and sew apparel manufacturing	3.1983	Monetary authorities and depository credit intermediation	4.2104
Apparel accessories and other apparel manufacturing	2.2154	Nondepository credit intermediation and related support activities, funds, trusts, and lessors	3.4553
Leather and hide tanning and finishing	1.6183	Securities, commodity contracts, and other financial investments and related activities	2.3946
Footwear manufacturing	1.4995	Insurance carriers	2.9116
Other leather and allied product manufacturing	2.3166	Agencies, brokerages, and other insurance related activities	4.8054
Sawmills and wood preservation	2.1434	Real estate	5.2959
Veneer, plywood, and engineered wood product manufacturing	2.3009	Automotive equipment rental and leasing	6.0129
Other wood product manufacturing	1.9179	Consumer goods rental and general rental centers	4.8305
Pulp, paper, and paperboard mills	1.7935	Commercial and industrial machinery and equipment rental and leasing	3.7971
Converted paper product manufacturing	2.4021	Legal services	4.0143
Printing and related support activities	3.4193	Accounting, tax preparation, bookkeeping, and payroll services	5.1806
Petroleum and coal products manufacturing	1.9186	Architectural, engineering, and related services	3.4984
Basic chemical manufacturing	1.9034	Specialized design services	3.1155
Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing	1.6205	Computer systems design and related services	2.4576
Pesticide, fertilizer, and other agricultural chemical manufacturing	2.1626	Management, scientific, and technical consulting services	4.0996
Pharmaceutical and medicine manufacturing	1.4046	Scientific research and development and other professional, scientific, and technical services	2.3168
Paint, coating, and adhesive manufacturing	3.0218	Advertising and related services	3.1589

Commodity	$?_g$	Commodity	$?_g$
Soap, cleaning compound, and toilet preparation manufacturing	2.1639	Management of companies and enterprises	4.3010
Other chemical product and preparation manufacturing	1.7060	Office administrative and facilities support services	4.8180
Plastics product manufacturing	3.0230	Employment services	4.1601
Rubber product manufacturing	2.0651	Business support and investigation and security services and support services, nec	2.3023
Clay product and refractory manufacturing	3.4073	Travel arrangement and reservation services	4.4194
Glass and glass product manufacturing	2.0243	Services to buildings and dwellings	4.9615
Cement and concrete product manufacturing	3.3664	Educational services	3.7035
Lime and gypsum product manufacturing	2.5085	Offices of health practitioners	4.1206
Other nonmetallic mineral product manufacturing	1.2256	Ambulatory health care services except offices of health practitioners	4.1628
Iron and steel mills and ferroalloy manufacturing	1.7678	Hospitals	2.9049
Steel product manufacturing from purchased steel	2.2098	Nursing care and residential mental health facilities	3.9219
Alumina and aluminum production and processing	2.0269	Community care facilities for the elderly and residential care facilities, nec	2.7640
Nonferrous metal (except aluminum) production and processing	1.4690	Individual, family, community, and vocational rehabilitation services	2.7061
Foundries	1.2111	Child day care services	4.8231
Forging and stamping	1.6281	Performing arts companies, promoters, agents, managers and independent artists	2.3653
Cutlery and handtool manufacturing	2.0703	Spectator sports	3.4074
Architectural and structural metals manufacturing	2.4124	Museums, historical sites, and similar institutions	2.7245
Boiler, tank, and shipping container manufacturing	1.7294	Amusement, gambling, and recreation industries	2.2665
Hardware manufacturing	2.2715	Traveler accommodation	3.8086
Spring and wire product manufacturing	2.8136	RV parks, recreational camps, and rooming and boarding houses	3.1258
Machine shops; turned product; and screw, nut, and bolt manufacturing	1.8308	Food services and drinking places	6.2679
Coating, engraving, heat treating, and allied activities	2.4728	Automotive repair and maintenance	5.6099
Other fabricated metal product manufacturing	1.9149	Electronic and precision equipment repair and maintenance	3.1270
Agriculture, construction, and mining machinery manufacturing	2.3320	Commercial and industrial equipment (except automotive and electronic) repair and maintenance	3.1691
Industrial machinery manufacturing	1.7741	Personal and household goods repair and maintenance	3.4986
Commercial and service industry machinery manufacturing	2.1161	Personal care services	4.6283
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	2.1333	Death care services	4.2690
Metalworking machinery manufacturing	1.6754	Drycleaning and laundry services	6.3393
Engine, turbine, and power transmission equipment manufacturing	1.4868	Other Personal Services	5.7096
Other general purpose machinery manufacturing	2.4345	Religious, grantmaking and giving services, and social advocacy organizations	4.6049
Computer and peripheral equipment manufacturing	2.1766	Civic, social, business, and similar organizations	3.8753
Communications equipment manufacturing	1.2119	Private households	6.2455

Commodity	$?_g$	Commodity	$?_g$
Audio and video equipment manufacturing	1.0359	Federal government	1.7158
Semiconductor and other electronic component manufacturing	2.2779	State government	2.7111
Navigational, measuring, electromedical, and control instruments manufacturing	1.4620	Scrap, used and secondhand goods	1.7198
Manufacturing and reproducing magnetic and optical media	2.2371	Labor	3.2679
Electric lighting equipment manufacturing	1.9793	Unemployed labor	1.3099
Household appliance manufacturing	2.3121	Investors	1.3270
Electrical equipment manufacturing	2.0384		

It is reassuring to note the instances where the elasticity of substitution is found to be extremely large, and where they are found to be extremely small. The largest elasticities of substitution are found primarily in the retail and service commodities, where we would expect to see very little interregional trade. On the other hand, the smallest elasticities of substitution are concentrated in the manufacturing commodities, where we would expect the quest for a specific type of a commodity to dominate the transportation cost of shipping the commodity. Remember that the process of estimating elasticities of substitution includes explicit calculation of all transportation costs, so the elasticity calculation is in no way polluted by the per unit transportation expense of shipping the commodity under examination.

Compatibility of the results with economic intuition is further clarified in table 2, where the average $?_g$ values and the standard deviation of the $P_{g\tilde{r}t}$ values are reported for manufacturers and non-manufacturers for each of the three modes. One will note that, in these broad categories, the results conform very nicely to expectations. As was suggested by table 1, the average estimated $?_g$ value for non-manufacturing is significantly smaller than the value for manufacturing commodities. This would be consistent with the intuition that non-manufacturing commodities are predominantly produced for consumption in relatively local markets, while manufacturers connect to more remote markets.

Table 4.2: Comparison of the estimated elasticity of substitution $?_g$ and standard deviation of ex works price $P_{g\tilde{r}t}$ for manufacturing and non-manufacturing commodities.

NAICS	**Commodity**	**Average** $?_g$	**Std. Dev.** $P_{g\tilde{r}t}$
31-33	Manufacturing	2.0947	0.1886
11-23, 42-92	Non-Manufacturing	3.4605	0.1014

The $P_{g\tilde{r}t}$ values, you will recall, is the cost of production less all transportation related expenses. The standard deviation is included here because intuition would suggest that many non-manufacturing activities, in addition to facing high elasticities of substitution, also face an otherwise relatively homogenous set of location specific prices. For example, aside from market access, the decision of where to offer retail gasoline has few region-specific decision components; on the other hand, the decision of where to locate paper manufacturing is driven by a number of location-specific characteristics independent of market access (e.g. access to water). Because of this, we would expect that the standard deviation of these location fixed effects would be higher for manufacturing firms (which face a set of, to the eyes of the producer, heterogeneous locations) and lower for non-manufacturing (which will tend to view all regions as more homogeneous). This is, indeed, the case. The one set of non-manufacturing commodities that is marked by very high deviation in the $P_{g\tilde{r}t}$ values is mining, which happens also to be a set of commodities with very obvious location heterogeneity.

To further validate the model, and to offer comparison to previous approaches to trade flow estimation in the United States that rely on the Commodity Flow Survey, we use the estimated $?_g$ coefficients and the $P_{g\tilde{r}t}$, and B_{grt} balancing factors to estimate a complete set of trade flow matrices following equation (4.17), for 2002 for the 3110 regions used in the model. The individual county trade flows matrices are then collapsed, to produce a 51 state (and DC) matrix of trade flows in the

United States for each commodity. The row and column representing Washington, DC is then dropped from each matrix, as the CFS excludes DC from their interstate trade flow data. Finally, because the CFS includes only manufacturing commodities, we may disregard all non-manufacturing commodities for purposes of comparison. The remaining 50x50 manufacturing trade matrices are then compared to the 2002 Commodity Flow Survey, which is generally used in estimating gravity models of regional trade in the United States.

However, the 2002 Commodity Flow Survey levels of trade in commodities among the various states does not conform perfectly to the aggregate levels of output and employment in the estimated model; that is, the CFS does not conform to REIS totals. Further complicating matters, as outlined by Schaffer and Chu (1969) and Harrington, McGilvary and McNicoll (1981), there does not exist any unique method for comparing the relative closeness of two matrices. However, estimating a correlation coefficient between the individual cells of the derived trade flow matrix and individual cells of the CFS matrix, on a commodity-by-commodity basis, will generate an estimate of the degree of comparability between estimated trade flows and the survey based estimation of goods shipped for each of the commodities. The resulting correlation coefficients are reported in table 3. Correlation coefficients are calculated separately for within state trade and between state trade, to better identify any divergence between correlation for short distance trade and long distance trade. Estimated correlations are generally quite high, over 70% for all but one commoditty, and over 80% for 18 of the 21 commodities. Correlations for the beverage and tobacco and chemical commodities are much lower; for beverage and tobacco, the correlation with the CFS is only 54%, and for chemical it is only 63%. This might be the result of the comparatively small number of producing regions (and hence the small number of observed trade flows), or an artifact of the fact that both types of manufactured goods are closely tied to a relatively immobile inputs or are subject to significant nonmarket pressures, or because of the tremendously broad range of activities within these commodity categories. Within any given commodity category, the within and between region correlations are generally very similar, though the beverage and tobacco commodity once again stands out, as the correlation coefficient for within state trade (73%) is much higher than the between state correlation coefficient. The regression of CFS trade flows of model derived trade flows was statistically significant for all commodities, for both within state and between state trade flows.

Table 4.3: Correlation between estimated trade flows and actual CFS shipments.

NAICS	**Commodity**	$T_{g\tilde{r}rt}$ **vs.** $CFS_{g\tilde{r}rt}$	$T_{g\tilde{r}\tilde{r}t}$ **vs.** $CFS_{g\tilde{r}\tilde{r}t}$
311	Food Manufacturing	0.94424	0.95359
312	Beverage and Tobacco Product Manufacturing	0.53834	0.73249
313	Textile Mills	0.79365	0.94105
314	Textile Product Mills	0.81334	0.84128
315	Apparel Manufacturing	0.91124	0.89881
316	Leather and Allied Product Manufacturing	0.92807	0.92224
321	Wood Product Manufacturing	0.94853	0.9614
322	Paper Manufacturing	0.92785	0.9295
323	Printing and Related Support Activities	0.86383	0.87087
324	Petroleum and Coal Products Manufacturing	0.94435	0.95502
325	Chemical Manufacturing	0.6325	0.6083
326	Plastics and Rubber Products Manufacturing	0.84051	0.87406
327	Nonmetallic Mineral Product Manufacturing	0.90772	0.91773
331	Primary Metal Manufacturing	0.95139	0.94435
332	Fabricated Metal Product Manufacturing	0.88847	0.88066
333	Machinery Manufacturing	0.96019	0.96987
334	Computer and Electronic Product Manufacturing	0.93984	0.96272
335	Electrical Equipment, Appliance, and Component Manufacturing	0.96613	0.97801
336	Transportation Equipment Manufacturing	0.85448	0.8525
337	Furniture and Related Product Manufacturing	0.8668	0.88462
339	Miscellaneous Manufacturing	0.83479	0.86933

While the generally high degree of correlation between the CFS and derived trade flow matrices is reassuring, the correlation between the two matrices, revealed in table 4.3, can be used to neither validate nor invalidate the approach outlined in this paper; recall that the CFS, by design, reports shipments, which are only imperfectly correlated with actual trade. As a survey, it is subject to all of the usual constraints (statistical error, measurement error, selection bias, etc.) of a survey. The derived trade flow matrix is grounded on a full census of producers, but involves extensive data manipulation and a fundamental reliance on the correctness of the theory. In addition, a shipment as measured in the CFS does not necessarily represent a purchase or sale. A shipment from a retailer's regional warehouse to their retail outlet, for example, would appear in the CFS, but does not represent a sale and is not desirable in an estimate of commodity trade flows. The CFS may also count the shipment of a single sale more than once, as the single shipment changes carriers and modes in moving from the supplier to the demander. These shipments should count as a single move from origin to ultimate destination for purposes of modeling trade flows. Despite these shortcomings, the results do suggest that this method for estimation of trade flows is not wildly divergent from the best proxy for trade available, and will, therefore, not diverge wildly from more traditional trade estimation techniques.

Conclusions

In this chapter, we present an alternative technique for the estimation of gravity models, a technique that does not rely in any way upon actual trade flow data. Instead, this method relies upon panel data for the regions and commodities under consideration to track the degree to which the location of production changes with the changing location of demanders. The estimated elasticities of substitution are generally consistent with our intuition and estimated trade flows are generally consistent with actual shipping data from the 2002 Commodity Flow Survey. The specific gravity model estimated in this chapter allows the modeler to explicitly estimate the transportation cost of shipping the commodity by each of the five modes of transportation, as well as estimating the all-important elasticity of substitution among individual varieties of each of the commodities. This estimation procedure simultaneously demonstrates the robustness of the gravity model and offers promise for its use in situations where trade data is not available.

The methods outlined in this chapter opens several possible avenues for future research. For example, this technique could be used over several years of panel data to examine both the spatial and the temporal aspects of distance decay parameters, a potentially critical issue raised by Fotheringham (1981). A similar method could readily be applied to determining border effects between states, regions, or countries.

Beyond simply exploring trade flows, this approach might also be applied to any number of spatial issues in the social sciences, where panel data is available and one or more spatial components are theorized, but where the "trade" component is not available, or perhaps not even directly measurable.

Chapter 5

THE NEW ECONOMIC GEOGRAPHY FRAMEWORK OF THE MODEL

Moving From Trade Flows to a CGE Model

Now that we have developed a complete database of supply, demand, and trade flows for each county in the United States, we have all of the information required to build a multi-region, multi-year input-output model of the United States economy. If we choose to effectively "lock down" the trade flow relationships in the model, we can build a multi-region, multi-year input-output model that is capable of calculating the economic impact on all regions of expanding or contracting the demand for any commodity, in any region. In an effort to find application for the work to this point, such a model was constructed; a complete technical description of the process used to build the model can be found in appendix D, and the results of an application of that model can be found in appendix E.

However, we are greatly interested in moving beyond traditional input-output models, and developing a true, county level computable general equilibrium model of the United States economy. Such a model would account for the effects of price fluctuations to clear all of the various markets in the model, and would presumably give a more accurate picture of the impact of exogenous shocks to the economy.

We mention in the previous chapter that there are any number of production functions that can be used to drive a gravity model. Our choice to use the Dixit-Stiglitz production function was driven not only by its relative ease-of-use and intuitive reasonableness, but also because it is completely compatible with the so-called "new economic geography" literature, which we will use to develop the behavioral equations for our general equilibrium model of the economy. In this chapter, we will explore the nature of New Economic Geography models and use these principles to build our theoretical model framework.

Basics of New Economic Geography

The behavioral equations that will be used to characterize our regional model of the U.S. economy are founded upon the new economic geography tradition, particularly as laid out by Fujita, Krugman and Venables (1999). The underlying model, in most of the new economic geography literature, is one of Chamberlinian monopolistic competition, which is characterized by a symmetric, constant-elasticity-of-substitution Dixit-Stiglitz (1977) production function. While Fujita, Krugman and Venables go to great pains to keep their exposition as clear as possible, they nevertheless fall into the same morass of CES algebra that plague much of the theoretical work in the field. Exploring the theoretical literature quickly reveals many of the problems that face the researcher who attempts to develop a computable general equilibrium model based upon the new economic geography paradigm. Nevertheless, we shall attempt to do just that. Before proceeding to outline the basic behavioral equations in the model, it is worthwhile to introduce the theoretical foundations that mark the new economic geography literature.

A Single Region Version of the New Economic Geography

We shall begin be exploring economic activity in a world where all such a ctivity is concentrated at a single point. Our discussion will roughly parallel the description given by Neary (2000), though we will be exploring a fundamentally different agglomeration force (intermediate inputs), as opposed to the mobile capital agglomeration force that was explored by Neary. There are, in the most basic models, two commodities. For our model, we will consider a completely immobile land commodity, and a monopolistically competitive composite manufactured commodity, produced in many varieties under increasing returns to scale. The manufacturing sector uses land, and the manufactured commodity (as an intermediate input) in a Dixit-Stiglitz (CES nested Cobb-Douglas) production function, with unit cost W given by:

$$W ? R^{1??} P^{?} \tag{5.1}$$

where R is the land rent, P is the price index of the composite manufactured good, and $?$ is the budget share of the manufactured intermediate input in production. Obviously, production costs will depend positively on the price index P, and on the price of land. This will be a key in developing the intermediate goods version of the new economic geography model.

The aggregate utility of landowners in the model is given by a Dixit-Stiglitz function:

$$U ? M^{?} L^{1??}, \tag{5.2}$$

where L represents the landowners consumption of land, $?$ is the share of nominal land holder income Y spent on manufactured goods, and M is a CES sub-utility function derived from consuming manufactured goods:

$$M^{\frac{??1}{?}} ? \mathop{?}_{i?1}^{n} m_i^{\frac{??1}{?}} \tag{5.3}$$

In the sub-utility function, m_i is the amount of each variety of the manufactured good demanded and $?$ (which must exceed one) is the elasticity of substitution between varieties. For the sake of simplicity, we shall assume that the elasticity of substitution between varieties of the manufactured good is the same for manufacturing firms (purchasing the manufactured good as an input to the production process) as it is for landowners, so the CES sub-utility function in (5.3) applies for both manufacturers and landowners.

Under these conditions, the aggregate expenditures on the manufacturing good is given by:

$$E ? ?Y ? ?npq \tag{5.4}$$

where E, the total expenditures on manufactured goods, is the sum of landowner spending on manufacturing $?Y$, and the budget share $?$ of each of the n firm's revenue pq on intermediate manufactured goods.

Given the CES function that determines variety preference for both manufacturing firms and consumers, one can allocate manufacturing demand among the individual varieties according to a demand function:

$$m_i = E\left(\frac{p_i}{P}\right)^{-\sigma}\frac{1}{P} \tag{5.5}$$

Individual variety demand m_i is log linear in the variety's own price p_i, and total spending on the manufactured good E, where both are deflated by an aggregate manufacturing price index P:

$$P^{1-\sigma} = \sum_{i=1}^{n} p_i^{1-\sigma} \tag{5.6}$$

Now, consider the behavior of manufacturing firms. Because the manufacturing sub-utility function demonstrates a preference for diversity, and since there are increasing returns to scale, it is optimal for each individual firm to produce a distinct variety. As a result, the number of varieties consumed will equal the number of firms, n. Naturally, profit maximizing firm output q_i must equal the demand for that variety m_i. The representative manufacturing firm, therefore, faces the variety demand function (5.5). Here, a key feature of the Dixit-Stiglitz form will become apparent. Under the Dixit-Stiglitz specification, firms will remain blissfully unaware of the effects of their actions both on income Y, and on the industry price index P (see e.g. Krugman 1980). Under this simplifying assumption, the demand curve perceived by the typical firm is (with identical firms, and one variety per firm, we can omit the i subscripts):

$$q = EP^{\sigma-1}p^{-\sigma} \tag{5.7}$$

rather than the demand function given by (5.5). The value of $EP^{? ?1}$ is taken as given by the firm. Marginal revenue for a representative firm is then:

$$mr ? \frac{? \; ?1}{?} p \qquad (5.8)$$

Equations (5.7) and (5.8) now define two constant-elasticity curves in $?p, q?$ space, labeled D and MR, respectively, in Figure 5.1.

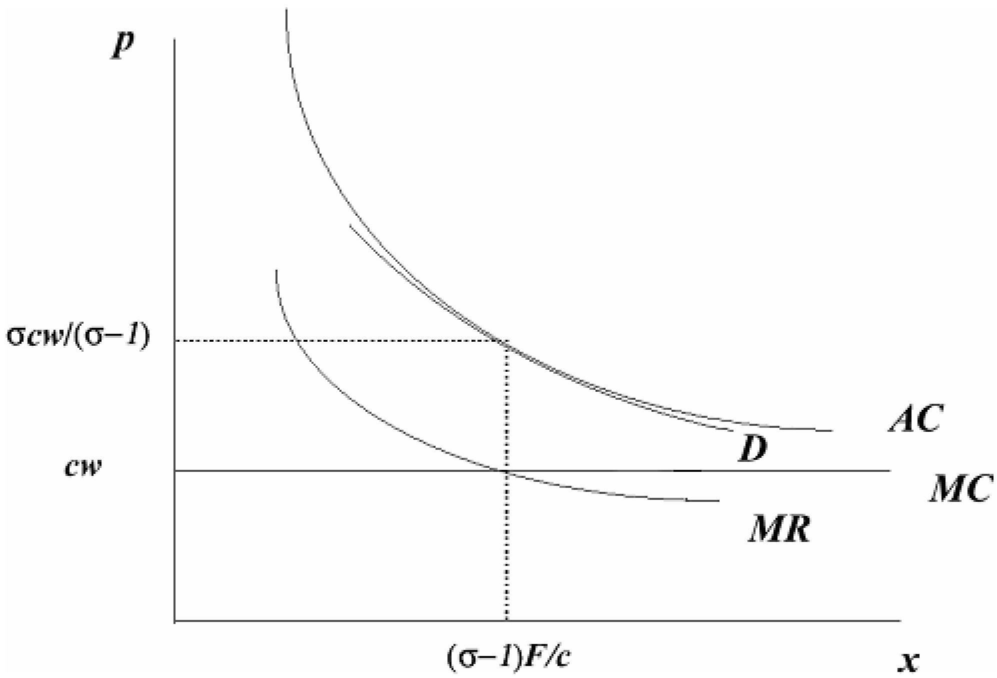

Figure 5.1: The Dixit-Stiglitz equilibrium.

The cost structure C of the representative firm is simply:

$$C ? F ? Wq \qquad (5.9)$$

where q is the output of the representative firm, fixed costs are given as F, and variable costs per unit output are W. This implies a horizontal marginal cost curve, and an average cost curve that is a rectangular hyperbola bounded by the vertical axis and the marginal cost curve. These curves are shown in Figure 5.1 as MC and AC.

Equilibrium for the firm under these conditions is given by the Chamberlain tangency condition, also shown in the figure. The careful selection of the functional form also generates a very simple set of expressions for equilibrium price and output. From profit maximization, marginal revenue equals marginal cost, or:

$$\frac{? \ ? 1}{?} p \ ? \ W \quad (5.10)$$

Therefore, the sales price mark-up over marginal cost depends entirely on $?$. However, free entry will drive firm profits to zero in equilibrium, so:

$$? \ ? \ pq \ ? \ ?F \ ? \ wq? \ ? \ 0 \quad (5.11)$$

Combining equations (5.10) and (5.11), we can calculate the equilibrium level of output for the representative firm as:

$$q \ ? \ ?? \ ? 1? \frac{F}{c} \quad (5.12)$$

As can be seen, the equilibrium level of output of each firm is totally independent of developments outside the industry: It depends entirely on the cost parameters F and c, and on the elasticity of substitution $?$. This is because changes in any other parameters, including such seemingly key variables as income Y and land rental rate R, will lead to adjustments in aggregate industry output entirely through changes in the equilibrium number of firms, as opposed to changes in the size of individual firms.

Spatial Interactions in New Economic Geography

So far, we have explored the new economic geography equations in a single region economy. Naturally, as the "geography" in new economic geography suggests, this is not the interesting framework for examining the implications of the theory. The basic behavioral assumptions of the one region model will also apply to a multi-region economy, at least so long as we make the typical assumptions of identical tastes, identical technology, and no barriers to trade. These are old assumptions, and should not be terribly surprising.

The key in introducing multiple regions to the new economic geography framework of the previous section is to remove the implicit assumtion of no barriers to trade by introducing transportation costs. This is traditionally done using the so-called "iceberg" assumption (Krugman, Fujita & Venables, 1999), wherein a constant fraction of output is lost in transportation. The introduction of any transportation cost into the framework removes us from the world of equalized factor prices, whether under Ricardian (one-factor) assumptions as in Krugman (1979), or Heckscher-Ohlin (two-factor) assumptions as in Helpman and Krugman (1985). This new world is fundamentally characterized by regional differences in goods and factor prices as in Krugman (1980).

A Two-Region Version of the New Economic Geography

Consider a hypothetical economy composed of two regions, labeled “1” and “2.” Now, lets assume that the cost of transporting a unit of the manufactured good, in either direction, is $T ? 1$ times the EXW price (the ex works price, or the price of the product at the producer’s door, before transportation costs). This is the traditional iceberg pricing mechanism, and is equivalent to assuming that, for every $T ? 1$ units shipped, only one unit arrives. The land good, which we disregarded entirely in the one region version of the model, will incur now be unshipable, so manufacturers can only use land in the region where they choose to produce. Surprisingly, this leaves our earlier equilibrium conditions largely unscathed. Apart from now adding region subscripts to utility, rent, and any other region-dependant variables, only two of our equations need to be altered to fully specify the new model. First, the demand function of the representative firm, equation (5.5), located in region 1 must be extended to include sales in both regions. For a representative manufacturer in region 1, the demand function becomes:

$$q_1 ? \left(E_1 P_1^{? ?1} ? E_2 P_2^{? ?1} T^{1??} \right) p_1^{??} \qquad (5.13)$$

Total demand now varies directly with the industry price indices and the level of manufacturing expenditure in both regions (P_1, P_2, E_1 and E_2), and inversely with the transportation costs T. However, the individual firms remain oblivious to all of these new complications, so the perceived demand function for the firm is still given by equation (5.5).

The only other equation that must be changed is the price index equation, (5.6). In a one-region economy equilibrium, all varieties will sell for the same price, so equation (5.4) can be specified simply as:

$$P^{1??} \ ? \ np^{1??} \qquad (5.14)$$

In our two-region economy with transport costs, the consumer prices of manufactured goods from different regions are not the same. Specifically, the n_1 domestic varieties cost p_1, while the n_2 imported varieties cost $p_2 T$. Therefore, the price index for region 1 becomes:

$$P_1^{1??} \ ? \ n_1 p_1^{1??} \ ? \ n_2 ?p_2 T ?^{1??} \qquad (5.15)$$

Note that, because every firm sells their variety in both markets, the price index is decreasing in the number of firms in both markets, and is increasing in trade costs. Equations (5.13) and (5.15) define a partial equilibrium in which, for given demands Y_1 and Y_2 and given rental rates r_1 and r_2, determine the equilibrium number of firms in both regions, n_1 and n_2, and the equilibrium price indices in both regions, P_1 and P_2. A key characteristic of these equations is that provided transport costs are strictly positive ($T \ ? \ 1$), region 1 is more responsive to changes in region 1 variables (income, wage, etc.), and region 2 is more responsive to changes in region 2 variables.

This asymmetry between the two regions has two powerful implications. To see this, it is first necessary to linearize the model around the symmetric equilibrium, and then consider a small increase in the size of region 1. Differentiating equation (5.15) gives us:

$$\hat{P} ? ?\frac{Z}{? ? 1}\hat{n} ? Z\hat{p} \tag{5.16}$$

where the circumflexes each represent a proportional rate of change. Z can be interpreted as an index of transport costs,

$$Z ? \frac{1 ? T^{1??}}{1 ? T^{1??}} \tag{5.17}$$

where $0 ? Z ? 1$. If we hold rental rates fixed for the moment, equations (5.16) and (5.17) identify what is called the "price index effect." Because imported manufactured goods incur transport costs, but home-produced manufactured goods do not, the cost of manufactured goods is lower the larger the market. Next, differentiating equation (5.13) gives us:

$$\hat{q} ? Z[\hat{Y} ? (? ? 1)\hat{P}] ? ?\hat{P} \tag{5.18}$$

If firm output and the price of each individual variety are fixed, an increase in demand can only be accommodated by a fall in the industry price index. Equations (5.16) and (5.17) dictate that a decrease in the industry price index can only be incurred by an increase in the number of varieties.

If we Substitute $\hat{P}$ out of equations (5.16), (5.17) and (5.18), we are left with

$$\hat{n} ? \frac{1}{Z}\hat{Y} \tag{5.19}$$

which identifies what is called the "home-market effect" (Krugman, 1980). Equation (5.19) tells us that the region with higher demand has a proportionately larger share of manufacturing, so long as $Z ? 1$.

The home-market effect is critical, since it predicts that the region with a larger home-market should be a net exporter of manufactured goods, at least in this very simple two-sector, two-region model. Krugman and Venables (1990) identify this as the core-periphery phenomenon, where larger regions have a disproportionately larger share of manufacturing.

Forces Behind the Home Market Effect in the Two-Region Model

The home-market effect is only one part of a theory of economic geography, since by itself this model assumes rather than explains regional differences in income. New economic geography models, which exhibit a propensity to agglomerate, require increasing returns and transportation costs, but also require some mechanism to actually bring about the agglomeration. While the mobile labor and mobile capital mechanisms have been the most extensively exploited, we will continue our approach by using intermediate inputs as the agglomeration force in our monopolistic competition model. As demonstrated initially by Wilfred Ethier (1982), incorporating intermediate inputs into a Dixit-Stiglitz model is a relatively straightforward affair, and Krugman and Venables (1995) and Venables (1996) demonstrated that they provide a route for agglomeration and lead to an analysis that is almost identical to that of labor and/or capital mobility. The fact that the intermediate input and labor and capital agglomeration forces all act in a remarkably similar way, this plays perfectly into our discussion in chapter 2, as we shall be treating "labor," "capital," and "intermediate inputs" as distinctions without a difference.

Begin by considering the behavior of the land sector/commodity. Recall that all land is immobile between regions, but mobile between sectors. In our two-region model, land can be traded freely between landowners and manufacturers in a region, but cannot be traded between regions. For simplicity, we shall assume that the regions are initially perfectly symmetric, with equal numbers in each region. If we are willing to assume that landowners all own an equal amount of land in both regions, then we can hold landholder income fixed, and simplify the solution considerably without changing any fundamental implications.

Firms, on the other hand, will be allowed to move between regions in response to differences in profits $?_1$ and $?_2$. The only relevant price index for any firm is the local price index in the region where the firm is located, as firms may purchase production inputs only in their home region. Now, we can explore the central theoretical question in the new economic geography: under what conditions will the economy (in equilibrium) exhibit an equal dispersion of manufacturing activity, and under what conditions will the economy exhibit agglomeration (the "core-periphery" solution)? As it turns out, these are actually two distinct questions; the equilibrium is not unique for all parameter values, and depends fundamentally on the “starting point” for the economy.

To see this, consider the case where the economy is in a symmetric dispersed equilibrium, and go through the following thought experiment. Assume that a single new manufacturing firm, for some reason, moves from region 2 to region 1, and consider how this affects the incentives for other firms. If profits in region 1 fall relative to region 2, the diversified equilibrium is stable, and the firm that moved is driven by falling profits to migrate production from region 1 back to region 2. The initial equilibrium is restored. However, if relative profits in region 1 rise, the symmetric, dispersed equilibrium is unstable. The increase in profits in region 1 encourages more firms to migrate to region 1, and the economy moves towards an equilibrium characterized by agglomeration, with more than half of multi-region manufacturing located in region 1.

The Competition Effect in the Two-Region Model

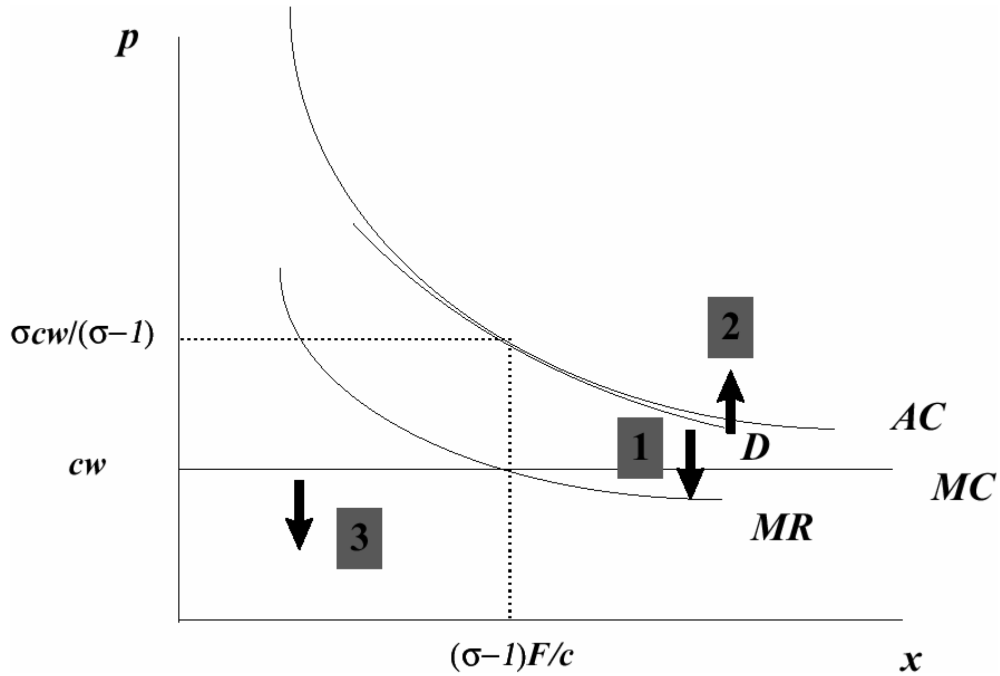

Figure 5.2: The effects of entry by a new firm on Dixit-Stiglitz equilibrium.

There are three effects of entry (Fujita & Thisse, 2002), each indicated by a numbered arrow in Figure 5.2. The competition effect dictates that an extra firm in region 1 lowers the industry price index, which reduces the demand facing each existing firm. The demand and marginal revenue curves shift downward, as indicated by arrow 1 in Figure 5.2. This "competition effect" reduces the profitability of firms, and hence always will act to encourage the dispersed equilibrium.

The Backward Linkage Effect in the Two-Region Model

The other two effects, on the other hand, will always act to encourage the core-periphery solution, and discourage/destabilize the symmetric, dispersed equilibrium. The "backward linkage effect" comes into play when the extra firm in region 1 raises the demand for the manufactured good in region 1. But, the increase in the manufactured good demand will tend to increase the price of the manufactured good in region 1. This upward shift in the demand curve leads to an upward shift in the marginal revenue curve as shown by arrow 2 in Figure 4.2. Clearly, this affect will tend to increase profitability in region 1 and encourage more firms to locate in region 1. This will tend to destabilize the symmetric, dispersed equilibrium and encourage a core-periphery solution.

Remember that, for the time being, we are assuming that landowner income remains unchanged, so the increased demand for manufactured goods in region 1 arises solely from increased intermediate demand, as opposed to increased final demand. Under this assumption, we can readily determine which of these first two effects will dominate. We know from equation (5.16), (5.17), and (5.18), that price-index effect depends entirely on Z. All other things being equal, higher transportation costs will mean that the initial movement of the firm from region 2 to region 1 will have a greater impact in lowering the price level and raising competition in region 1, while very low transportation costs will mean that the migration of the firm from region 2 to region 1 has only a very small effect on the region 1 price index.

Recalling equation (5.16), and again assuming nominal income remains constant, the backward linkage effect will dominate the price index effect, if and only if ? (the share of the manufactured intermediate input in the production of the manufactured good) is greater than Z. Put another way, the firm migrating from region 2 to region 1 raises the demand facing all existing firms only if ? is greater than Z. Because the initial dispersed equilibrium is definitively unstable when ? is greater than Z, agglomeration is most likely when the share of manufacturing in national income is high, and when transport costs are low.

The Forward Linkage Effect in the Two-Region Model

The condition that ? ? Z actually understates the forces acting to encourage the core-periphery solution, since firm location decisions are driven not only by increases in marginal revenue (as in the backward linkage effect), but also by decreases in marginal costs. As we have seen in the price index effect, the entry of the new firm in region 1 will decrease the price index for manufactured goods in region 1. But this causes yet another effect, a forward linkage effect, since it reduces the cost of the manufactured good, which reduces the price of the intermediate input in manufacturing, and so tends to increase profits in region 1. Because manufacturing firms are allowed to migrate between regions, the resulting migration will act to drive profits to zero, which means that the manufactured good price in region 1 must fall. The result of the forward linkage effect is a downward shift in the average and marginal cost curves shown by arrow 3 in figure 4.2; clearly, this effect acts to raise profitability in response to agglomeration, and so further encourages the core-periphery solution.

One feature that is unique to our particular model, is that land prices will offer a natural dispersion force, as continued firm migration into region 1 will simultaneously lead to decreased cost of manufactured inputs as described above, and increased land rental rates in region 1. This means that agglomeration into region 1 will not be absolutely complete. As ever more demanders of land migrate to region 1, the cost of land in region 2 approaches zero, while the price of the manufactured good in region 2 will approach p_2T. As such, complete outmigration from region 2 to region 1 would lead to infinite potential profits for manufacturers and/or infinite utility for landowners staying in region 2. Therefore, the agglomeration of activity in region 1 will never be absolute – some landowners, and/or some manufacturers, will always choose to locate in region 2.

The Break and Sustain Points in the Two-Region Model

Deriving the necessary and sufficient conditions for stability of the diversified equilibrium requires combining the three effects explicitly, and is not strictly necessary for this exposition, as our model will ultimately rely on an evolutionary algorithm as opposed to an explicit equilibrium calculation as in Neary (2000). However, it is fairly easy to see how the stability of the dispersed equilibrium is affected by changes in the three key parameters: transportation costs T, manufacturing share of production ?, and the elasticity of substitution ?. Higher transportation costs T always encourage stability of the dispersed equilibrium, and if transportation costs T are high enough, between-region shipments are so expensive that home production is always profitable. Very low transportation costs, on the other hand, will inevitably make the dispersed equilibrium unstable, since neither region will have a comparative advantage in production of the manufactured good for the home market. Somewhere between these extremes, we could identify a threshold level of transportation costs, T^B, referred to as the break point, where the dispersed equilibrium becomes unstable. The break point T^B must exist, so long as ? is strictly positive; that is, so long as there is any incentive for agglomeration.

We can now consider how the break point T^B changes with the other parameters. For example, we can see that T^B is increasing in ? , since the backward linkage and the forward linkage effects, both of which act to encourage agglomeration, increase in magnitude as ? increases. The greater the share of the manufactured good in production of the manufactured good, the greater the backward linkage, wherein the new firm entering region 1 increases region 1 demand, which increases profits, which induces firms to locate in region 1, which further raises demand and encourages further entry of manufacturers, and so on. The greater the manufacturing share ? , the greater the forward linkage, where entry of the new firm into region 1 lowers prices in region 1, which lowers production costs in region 1, which raises profits in region 1, inducing firms to locate in region 1, which raises demand and thereby encourages further entry of manufacturers into region 1.

The break point T^B is decreasing in ? , the elasticity of substitution in demand for the manufactured good. The larger the value of ? , the more consumers and producers will view different varieties as close substitutes. A large value of ? will lead to an equilibrium characterized by few varieties and a higher output of each variety. A large value of ? , therefore, will still mean that both regions are likely to hold on to some manufacturing production, even at low trade costs.

If transportation costs are lower than the break level T^B, then their must exist a stable core-periphery equilibrium (actually, as our economy is symmetric, there must exist two stable core-periphery equilibria – manufacturing concentrated in region 1, or manufacturing concentrated in region 2). However, while transportation costs below T^B are sufficient for a stable core-periphery solution, they are not necessary. Consider a different thought experiment, in which our hypothetical economy initially exhibits a core-periphery pattern. Let us assume that manufacturing is agglomerated in region 1, and let's explore what happens when our firm decides to "break with tradition" and move from region 1 back to region 2.

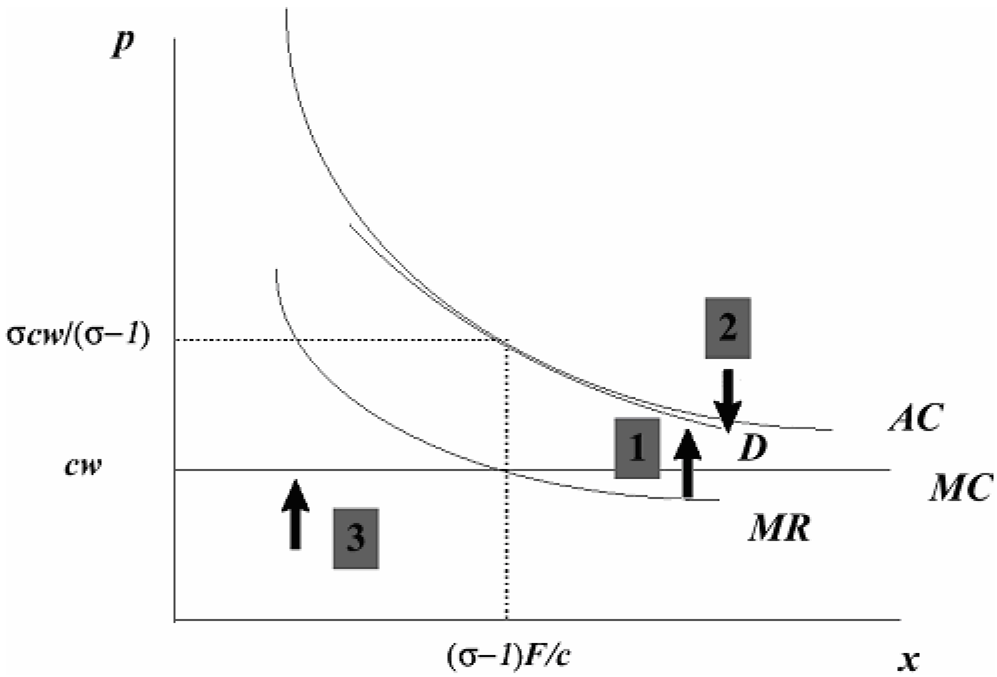

Figure 5.3: The effects of exit of firm on the Dixit-Stiglitz equilibrium.

We can now refer to figure 5.3, which illustrates the price index, and backward and forward effects of a firm migrating from the core to the periphery. If the initial equilibrium shown in figure 5.3 is region 1, then what forces come into play when a firm enters in the periphery? In this case, the price index effect dictates that the firm faces less competition from region 1 firms in serving region 2 consumers, which is represented by an increase in demand and in marginal revenue, shown by arrow 1 in figure 5.3. The backward linkage effect, however, dictates that the firm that moves to the periphery has less access to consumers in the core; this is shown in figure 5.3, arrow 2. Finally, the forward linkage effect tells us that, because the periphery has fewer manufacturers, a greater share of manufactured goods consumed there must be imported. All of that importing from region 1 incurs transportation costs, which means that the cost of production is higher in region 2, which cuts into profits. This forward linkage is represented by figure 5.3, arrow 3.

As one might guess from this intuitive description, there exists a second threshold level of transportation costs, T^S, called the sustain point. The sustain point represents the level of transportation costs past which the core-periphery solution is no longer an equilibrium. This new threshold has the same relationship to the underlying parameters as T^B, for the same reasons; as with T^B, T^S is increasing in ? and decreasing in ? .

We can also unambiguously rank the break and sustain points T^B and T^S; specifically, T^S ? T^B, so long as ? ? 0. Therefore, there is always some range of trade costs within which the dispersed equilibrium, and both of the core-periphery solutions, are all sustainable; that is, a range within which no firm would benefit by moving from a dispersed equilibrium, but neither would any firm benefit by moving away from an existing core-periphery arrangement.

Figure 5.4 illustrates the number and types of equilibria as a function of trade costs T, a classic graph referred to as the "tomahawk bifurcation" diagram. The vertical axis measures ? , the share of the world manufacturing located in region 1; solid and dotted lines denote stable and unstable equilibria, respectively. Recall that the regions are identical, so at every level of trade costs there exists a symmetric dispersed equilibrium, though this equilibrium may or may not be stable. Specifically, it is unstable for trade costs below T^B. Similarly, the core-periphery equilibrium ceases to exist for trade costs above T^S. At or below T^S, there are two symmetric, stable core-periphery configurations. Finally, between T^B and T^S, there are a total of three stable equilibria, one diversified and two agglomerated. It is this gap between T^B and T^S that allows for multiple equilibria and generates the hysteresis that characterizes new economic geography models.

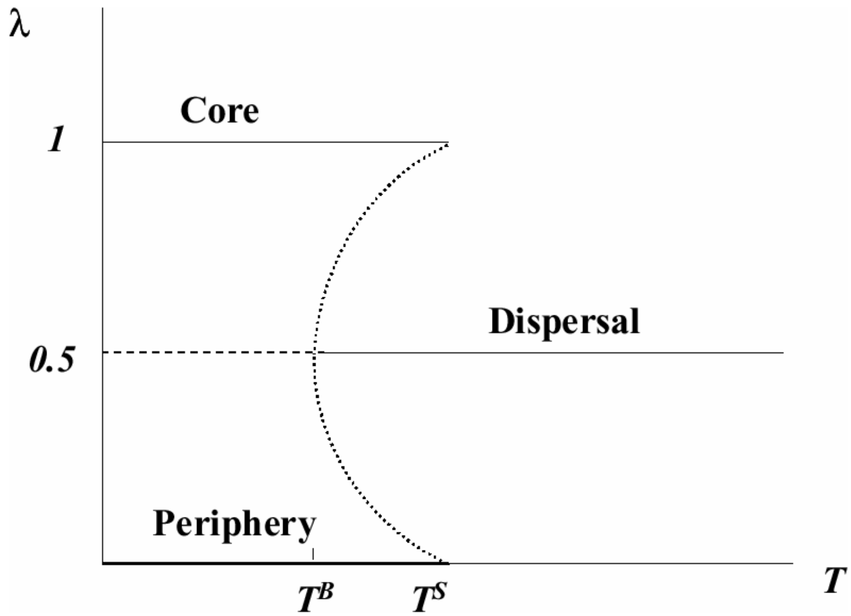

Figure 5.4: Tomahawk bifurcation diagram of equilibria as a function of trade costs.

Armed with the tomahawk bifurcation diagram, we can examine some basic dynamics of the new economic geography model. A decrease in transportation costs from an initial level, high enough for a stable dispersed equilibrium, will lead to catastrophic agglomeration once T^B is reached. If transportation costs then reverse and begin climbing, the dispersed equilibrium will not be reached until transportation costs rise above T^S; whichever region happens to first acquire the manufacturing agglomeration will continue to be the core, so long as transportation costs remain below T^S.

"Types" of New Economic Geography Models

NEG models come in a few basic types. One family of new economic geography models have developed around the basic framework we have outlined in this chapter, in which agglomeration comes as a result of the interaction of the home-market effect and input-output linkages among firms, such as those used by Venables (1996) and Krugman and Venables (1995). A similar trade model, including input-output linkages, was developed by Robert-Nicoud (2002) who combines vertical linkages with the model of Flam and Helpman (1987).

In a second family of NEG models, agglomeration is a result of the interaction of the home market effect (Krugman, 1980) and factor spatial mobility. Krugman's (1991a) mobile labor model assumes that labor in the manufacturing sector is mobile between regions and moves according to regional differences in real wages. A similar model developed in Forslid (1999) and Ottaviano (2001), was built on the trade model developed by Flam and Helpman (1987) on the assumption that owners of the manufacturing firms were mobile between regions, and migrated in response to profit signals.

And Why "Types" was put in Quotes…

Robert-Nicoud (2004) has shown that the mobile labor models of the Krugman (1991) type, the mobile firm model of Forslid (1999) and Ottaviano (2001), and the input-output/intermediate input models of Venables (1996) and Krugman and Venables (1995), can be entirely characterized by the same set of equations; in other words, the models are isomorphic. In particular, the natural state variable of these models is the mobile expenditure. This implies that the relevant variable to look at in empirical studies, based on these models, is the spatial distribution of expenditure or income of mobile factors, rather than population or firm distribution (Robert-Nicoud, 2004). We shall keep this conclusion foremost in our mind as we develop the model's behavioral equations. Also, because the models are isomorphic, it is sufficient to describe the properties of any of the models to know the properties of all of the models.

The fact that all of the key new economic geography models are isomorphic, irrespective of the agglomeration mechanism they are assuming, fit smoothly with our data structure developed in chapter 2, in which all sectors of the economy are treated as "industries," and are therefore isomorphic as well.

Because the new economic geography frameworks are isomorphic, the predictions of an empirical NEG model are robust to the assumption about the underlying agglomeration mechanism. This implies that the results of an empirical investigation, based on the reduced form of any model, are more general and could be derived from any other structural model, the only difference being in the interpretation of the structural parameters. This is not entirely good news, in that under these conditions it is difficult to identify the channel by which the agglomeration operates. All agglomeration mechanisms identified in the key NEG models, likely play a role in the real world. Since they all show up the same way in the reduced form, it is difficult to determine the magnitude of their respective roles.

Morphing the Isomorphic: In Empirical Application of the General NEG Framework

The behavioral equations that will drive our regional economic model will be built upon the data structure outlined in chapter 3, and the trade flow equation estimated in chapter 4, as well as the simple two region intermediate input NEG model outlined in this chapter. In our complete model, every entity will simply be a process/function for converting a menu of commodities into another menu of commodities. This allows us to drive the model with a single family of behavioral equations, as opposed to a set of functions for businesses, another set for households, another set for governments, and so on. Commodities may differ in terms of substitutability or physical location, and industries may differ in terms of location and the mix of inputs and outputs, but all such differences may be subsumed into differences in parameter values; one need not resort to fundamentally different behaviors, as every entity is optimizing given their unique situation (industry type, location, time period). As we shall see, this can be done without torturing the model structure in the least; indeed, I would go so far as to say that the resulting model structure is much more coherent and defensible than most applied models of regional economies.

By strictly adhering to the strategy of “everything is an industry and everything acts the same,” the resulting simplicity allows us to attack several issues previously dealt with in the literature on only a piecemeal basis. The model, for example, will not resort to a strict assumption of iceberg type transportation costs. Rather, the transportation component of production will be modeled in a very explicit manner. This model will generate its centripetal, dispersal force solely from demand for a fixed quantity of land in each region and its gravitational force from the shipping cost of each of the commodities in the model. The model also includes a government tax/spending force, which may act to encourage or discourage economic agglomeration, as we shall see in the fullness of time. This mechanism of a single set of behavioral assumptions, with a single attractive force and a single dispersionary force, and a single government induced force that might act in either direction, allows the model to be tractable for virtually any number of industries. This will jointly produce virtually any number of commodities in virtually any number of regions. It is this “expandability” that will be used to full effect when we bring the behavioral model to the data.

Chapter 6

A COUNTY LEVEL NEW ECONOMIC GEOGRAPHY MODEL OF THE UNITED STATES ECONOMY

Behavioral Equations of our Applied NEG Model of Regional Economies

Expanding our model structure from chapters 3 and 4, to fully incorporate the new economic geography framework outlined in chapter 5, will prove to be a remarkably straightforward affair. In this chapter, we will build a set of behavioral equations consistent with our data and apply those equations to build an NEG model of the United States economy.

Regardless of the type of entity in question, each will face a Dixit-Stiglitx production function of the form:

$$\underset{g?1}{\overset{G}{?}} ?\tilde{g}_{gmirt}?^{?_{\tilde{g}it}} \; ? \; E_{it} \; ? \; q_{mirt} \qquad (6.1)$$

for each manufacturer m, belonging to industry i, located in region r, at time t. G represents the total number of goods in the economy. $\tilde{g}_{gmirt}$ is the quantity of composite commodity good $\tilde{g}$ used by manufacturer m, in industry i, in region r, at time t. $?_{\tilde{g}it}$ is the share of composite commodity good $\tilde{g}$, used in industry i, at time t. That is, the production function at any point in time is industry and time specific, but not region or manufacturer specific. E_{it} is the fixed cost of production for industry i at time t. Finally, q_{mirt} is the total output of manufacturer m, in industry i, in region r, at time t.

This behavioral equation will apply to all entities, regardless of the "type" of entity in the traditional sense. For example, a labor manufacturer will use a mix of inputs to produce a labor commodity for sale to those manufacturers who demand such commodities. Implicitly, this amounts to the traditional cost minimization exercise for households and other “final demanders,” but that distinction is artificial for purposes of this model.

Regardless, again, of the entity in question for the variables as defined in equation (6.1), every manufacturer also faces the traditional Cobb-Douglas budget share constraint given by:

$$\overset{G}{\underset{g?1}{?}} ?_{git} ? 1 \tag{6.2}$$

Note that the budget share constraint implies constant returns to scale at the firm level. This is consistent with agglomeration economies in the new economic geography framework, which are based on increasing returns at the industry level, but not at the firm level.

Because we wish to allow for the possibility of joint production, as implied by our data structure described earlier, we must also specify:

$$q_{mirt} ? \overset{G}{\underset{g?1}{?}} ?_{git} q_{mirt} \tag{6.3}$$

So,

$$\overset{G}{\underset{g?1}{?}} ?_{git} ? 1 \tag{6.4}$$

where $?_{git}$ is the output share of good g in industry i, at time t.

In order to best facilitate the joint production component of the model (which is dictated by the fact that the United States IO tables show most industries do produce multiple commodities), we shall calculate the U.S. average inputs for commodity g at time t, given by:

$$?_{\tilde{g}gt} ? \overset{I}{\underset{i?1}{?}} ? ?_{\tilde{g}it} \frac{Q_{git}}{\overset{I}{\underset{i?1}{?}} Q_{git}} ? \tag{6.5}$$

where $?_{\tilde{g}gt}$ is the input share of commodity $\tilde{g}$ used in the production of commodity g, at time t, I is the total number of industries, $?_{\tilde{g}it}$ is the input share of commodity $\tilde{g}$, in industry i, at time t, and Q_{git} is the output of commodity g, by industry i, at time t. To simplify the process of calculating prices across all regions and commodities in the model, we shall use these input shares in all price and trade calculations.

As previously noted, there is another major departure from earlier new economic geography models. The model we are developing will not rely upon iceberg costs, and instead, will explicitly model the transportation component of the economy. The iceberg transportation cost assumption is so thoroughly embedded in the new economic geography literature, that it is identified by Krugman, Fujita and Venables (1999) as one of the three cornerstones of the literature. The step of abandoning iceberg costs is not taken lightly, but since tractability can be maintained with a more realistic transportation assumption, abandoning iceberg transportation cost is the best course of action. For this model, transportation cost will be given by:

$$\frac{P_{g\tilde{r}rt}}{P_{g\tilde{r}t}} ? \overset{?}{\underset{? ? 1}{?}} ?_{g?t} d_{?\tilde{r}rt}^{\;?_{?gt}} \qquad (6.6)$$

where the left hand side of the equation, $\frac{P_{g\tilde{r}rt}}{P_{g\tilde{r}t}}$, represents the ratio of the profit-maximizing price as delivered to region r to the profit-maximizing Ex Works (EXW) price for good g, produced in region $\tilde{r}$, at time t. ? represents the number of modes of transportation. Each mode of transportation, as mentioned earlier, is a commodity in the overall economy, hence ? ? G. $d_{?\tilde{r}rt}$ represents the effective distance from region $\tilde{r}$ to region r by mode $?$, at time t. $?_{?gt}$ is the share of transportation commodity $?$, used in production of commodity g, at time t, and $?_{g?t}$ represents the unit distance cost of shipping commodity g, by mode $?$, at time t. In estimating NEG models, the concept of $d_{?\tilde{r}rt}$ is often approximated by straight-line distance or an average travel time between two regions. However, we will continue to use our explicit transportation infrastructure approach outlined earlier and in appendix C.

Under this explicit transportation cost assumption, the profit-maximizing price in region r of commodity g, produced in region $\tilde{r}$, by industry i, at time t becomes:

$$P_{g\tilde{r}rt} ? P_{g\tilde{r}t} ? ?_{? ? 1}^{?} ?_{g?t} d_{?\tilde{r}rt}^{?_{?gt}} \tag{6.7}$$

The next task is to define the vector of EXW profit-maximizing prices for all commodities manufactured in region $\tilde{r}$ at time t:

$$P_{g\tilde{r}t} ? \frac{?_g}{?_g ? 1} ?_{g\tilde{r}t} \tag{6.8}$$

where $?_g$ represents the elasticity of substitution between individual varieties of commodity g, and $?_{g\tilde{r}t}$ is the marginal cost function for producing commodity g in region $\tilde{r}$ at time t.

By working within price (rather than quantity) space, as dictated by the isomorphic discovery of Robert-Nicoud (2004), the EXW marginal cost function $?_{grt}$ is in turn given by:

$$?_{grt} ? ?_{\tilde{g}?1}^{G??} ?P_{\tilde{g}rt}?^{?_{\tilde{g}gt}} \tag{6.9}$$

where $G ? ?$ is the number of non-transportation commodities, $P_{\tilde{g}rt}$ is the price index of commodity $\tilde{g}$, in region r, at time t, and $?_{\tilde{g}gt}$ is the share of commodity $\tilde{g}$ used in production of commodity g at time t. This vastly simplifies the marginal cost functions used by others (e.g. Fan, Treyz & Treyz, 2000) in developing multi-industry NEG models.

The price index $P_{\tilde{g}rt}$ is given by:

$$P_{\tilde{g}rt} = \sum_{\tilde{r}=1}^{R} \left(\frac{T_{\tilde{g}\tilde{r}rt}}{\sum_{\tilde{r}=1}^{R} T_{\tilde{g}\tilde{r}rt}} P_{\tilde{g}\tilde{r}rt} \left(\frac{\sum_{r=1}^{R} D_{\tilde{g}rt}}{\sum_{\tilde{r}=1}^{R} Q_{\tilde{g}\tilde{r}t}} \right) \right) \qquad (6.10)$$

where R represents the total number of regions in the model. $T_{\tilde{g}\tilde{r}rt}$ is the total trade in commodity $\tilde{g}$, originating in region $\tilde{r}$ and sold to region r, at time t, and $P_{\tilde{g}\tilde{r}rt}$ is the profit-maximizing price in region r of commodity $\tilde{g}$, produced in region $\tilde{r}$, at time t. The ratio of total demand in all markets, $\sum_{r=1}^{R} D_{\tilde{g}rt}$ to total supply in all markets $\sum_{\tilde{r}=1}^{R} Q_{\tilde{g}\tilde{r}t}$, might seem superfluous. Remember that the national IO tables are balanced by design, and hence, this ratio should equal 1 and be irrelevant to the calculation – and indeed, in most situations, this is the case. However, we will impose a few simple market restrictions that will act on the model through this ratio.

Because we are re-envisioning the various economic agents such that all agents are simply profit-maximizing producers, each of which is transforming one menu of commodities into another menu of commodities, this single set of behavioral equations is sufficient to define the entire economy. These equations will not only define the behavior of all firms in the model, but also the behavior of all workers, all non-workers, all governments, all investors, and all speculators, in all regions of the model. That said, some restrictions and assumptions will be imposed upon the various entities in the model to capture specific behavioral limitations. The restrictions that will be imposed are as follows:

1. No local government commodity can be shipped across county lines. This, effectively, prevents the export of local government commodities across region borders, which means that local government is paid for entirely by those entities in the region. Because this model will use counties as regions, this amounts to an assumption that local government does not cross county borders, but is provided uniformly within any given county; this is certainly a simplifying abstraction from reality, to the extent that some local government

entities cross county borders, while others may not have a footprint that does not cover an entire county.

2. No state government commodity can be shipped across state borders. This has the same effect for state government as our first assumption did for local government – state government does not cross state borders, but may be transported within the state, though such shipments are subject to the explicitly estimated transportation cost for the commodity.
3. Land cannot be shipped across county borders. Recall that the land area in a region fixes the supply of the land commodities in the region. This means that any region has a fixed supply of land, and this will act as the fundamental dispersing force in the model, counteracting any tendency toward catastrophic agglomeration that might occur in the presence of transportation cost alone.

These three restrictions will act on the price of these commodities through the total market demand to total market supply ratio in equation (6.10). For example, the price index for land in a county will be driven by the ratio of total budget share of all industries in the county going to land, to total land area in the county. In any market that is national in scope, the demand/supply ratio is one by design of the national IO table; but for the state government, local government, and land variables, the ratio in any given market may be any positive number. This is most critical for the land commodity, as this will act as the primary dispersionary force in the model.

With this set of equations and market restrictions, all of the information is available to begin estimating a set of model parameters. We have already estimated the elasticity of substitution $?_g$ between individual varieties of commodity g, for each commodity in the model in chapter 4. Next, we will take our trade flow estimates, together with the behavioral equations outlined in this section, to develop our county level new economic geography model of the U.S. economy.

Creating CGE and Dynamic Adjustment Paths for the Model

In our trade flow estimation process in chapter 4, we estimated a critical variable, but did not make any effort to explain the theoretical underpinnings of that variable. To generate our dynamic new economic geography model of the economy, it is critical that we unwrap the concept of the EXW price of good g. Under the new economic geography framework outlined above, we see that the EXW price can be decomposed as:

$$P_{grt} = \frac{\sum_{r=1}^{R} D_{grt}}{\sum_{r=1}^{R} Q_{grt}} \cdot \prod_{\tilde{g}=1}^{G??} \left(P_{\tilde{g}rt}\right)^{?_{\tilde{g}gt}} \cdot A_{gr} \qquad (6.11)$$

That is, the EXW price P_{grt}, is equal to the demand to supply ratio of the commodity in the market (per equation 6.10) times the production function weighted price index for all nontransportation intermediate inputs. The refinement that we must introduce at this point is the variable A_{gr}, which is the first nature production cost of commodity g in region r. The EXW price equation (6.10) is correct, only if there are no location specific price differences in production for any region, except those originating from the price of intermediate inputs. However, in the real world, regions are intrinsically heterogeneous. For example, coal mining is intrinsically more profitable in Wyoming than in Delaware, not because market access is better in Wyoming than in Delaware, but because Wyoming is intrinsically different than Delaware – Wyoming has lots of rich coal deposits, and Delaware does not. Likewise, boat building will tend to be more profitable when there is a body of water in the region, agriculture will be more profitable for regions that have the appropriate soil, etc. In a completely homogenous world, there would be no such first nature differences, all A_{gr} values would be expected to equal 1, and the only other force driving the location decision would be market access.

But with our CGE behavioral equations, and with our trade flow calculations from chapter 4, we can estimate a complete new economic geography model.

We begin with the trade relationship that was estimated in chapter 4, equations (4.21), (4.14) and (4.15):

$$\frac{Q_{g\tilde{r}t}}{Q_{g\tilde{r}t-1}} = \frac{\sum_{r=1}^{R} D_{grt}\left[B_{grt}\left(\prod_{\kappa=1} d_{\kappa\tilde{r}rt}^{\delta_{\kappa gt}}\right)\right]^{-\sigma_g}}{\sum_{r=1}^{R} D_{grt-1}\left[B_{grt}\left(\prod_{\kappa=1} d_{\kappa\tilde{r}rt-1}^{\delta_{\kappa gt-1}}\right)\right]^{-\sigma_g}} \tag{6.12}$$

$$P_{g\tilde{r}t}^{-\sigma_g} = \left[\sum_{r=1}^{R} D_{grt}\left(B_{grt}P_{g\tilde{r}rt}\right)^{-\sigma_g}\right]^{-1} \tag{6.13}$$

$$B_{grt}^{-\sigma_g} = \left[\sum_{\tilde{r}=1}^{R} Q_{g\tilde{r}t}\left(A_{g\tilde{r}t}P_{g\tilde{r}rt}\right)^{-\sigma_g}\right]^{-1} \tag{6.14}$$

which were used to estimate σ_g, B_{grt}, and $P_{g\tilde{r}t}$, and trade flows.

For each origin region $\tilde{r}$ and destination region r, for each good g, we calculate the delivered price equation (6.7) for the last history year using our calculated EXW price $P_{g\tilde{r}t}$ from equation (6.13). Once we have calculated the delivered price for all regions and commodities in the last history year, we can use equation (6.10) to calculate the price index for every commodity and region in the last history year. Finally, the EXW price for every commodity is decomposed into its respective elements, per equation (6.11), specifically to identify the first nature differences, A_{gr}, for each good and region in the last history year. We shall assume that these first nature differences do not fluctuate over time.

Once these calculations are made, there is certainly no guarantee that profits of all industries, in all regions, will be equal. Given the monopolistic competition configuration of the model, any potential for profit will be realized in regions that can produce and deliver output at a low relative price within the various markets they serve. As such, given the behavioral equations outlined in the previous section, we can estimate an index of relative profitability for firms in industry i in region r at time t as:

$$?_{irt} = \sum_{\tilde{g}=1}^{G} \left(?_{\tilde{g}it} \left(\sum_{r=1}^{R} \left(\frac{T_{\tilde{g}\tilde{r}rt}}{\sum_{r=1}^{R} T_{\tilde{g}\tilde{r}rt}} \cdot \frac{P_{\tilde{g}rt}}{P_{\tilde{g}\tilde{r}rt}} \right) \right) \right) \quad (6.15)$$

where $?_{irt}$ is an index of relative profitability for industry i, in region r, at time t.

At this point, we must develop a two-step output adjustment process for the CGE model in order to recognize that the adjustment to a stable long run equilibrium is not an instantaneous process, but rather a series of myopic steps as each industry in each region makes adjustments, over time, in response to their profitability signals. The first step is to identify the share of total U.S. output in each industry that is mobile in a given year. We identify the degree to which total U.S. output in an industry is mobile (the share of total industry i output that may relocate in a given year, $?_i$) as:

$$?_i = \frac{1}{2} \cdot \frac{\sum_{r=1}^{R} \left| Q_{i\tilde{r}t} - Q_{i\tilde{r}t-1} \cdot \frac{\sum_{\tilde{r}=1}^{R} Q_{i\tilde{r}t}}{\sum_{\tilde{r}=1}^{R} Q_{i\tilde{r}t-1}} \right|}{\sum_{\tilde{r}=1}^{R} Q_{i\tilde{r}t}} \quad (6.16)$$

for each industry, for each region, we calculate the historical difference between the region's output, $Q_{i\tilde{r}t}$, and the output that would be expected if the region had grown at the U.S. average rate. By summing the absolute values of each regions difference, and dividing by two, and by the total US output in the last history year, we have an estimate of the share of U.S. output for the industry that has relocated; essentially, a measure of the degree to which the industry is "footloose."

An output adjustment process can then be applied to the footloose share of total industry output,

$$\frac{Q_{i\tilde{r}t?1}}{\sum_{\tilde{r}?1}^{R} Q_{i\tilde{r}t?1}} ? \frac{Q_{i\tilde{r}t}}{\sum_{\tilde{r}?1}^{R} Q_{i\tilde{r}t}} ? ?_i ? \sum_{\tilde{g}?1}^{G} ?_{git?1} ? \sum_{r?1}^{R} T_{\tilde{g}\tilde{r}rt} ? \frac{P_{\tilde{g}rt}}{P_{\tilde{g}\tilde{r}rt}} ? ? 1 ? ?_i ? \frac{Q_{i\tilde{r}t}}{\sum_{\tilde{r}?1}^{R} Q_{i\tilde{r}t}} \qquad (6.17)$$

where $Q_{i\tilde{r}t}$ and $Q_{i\tilde{r}t?1}$ are the quantity of output in industry i, in region $\tilde{r}$, at times t and $t ? 1$, respectively, and $?_i$ is the speed of adjustment of industry i to the relative profitability signal, and must be econometrically estimated.

Then, using our historical data, we can use equation (6.17) to calculate profitability response $?_i$ for each industry by least squares, using:

$$\frac{Q_{irt?1}}{\sum_{\tilde{r}?1}^{R} Q_{i\tilde{r}t?1}} \Bigg/ \frac{Q_{irt}}{\sum_{\tilde{r}?1}^{R} Q_{i\tilde{r}t}} ? 1 ? ?_i ? ?_{irt} ? 1 ? ?_i \qquad (6.18)$$

Based upon the calculated profitability $?_{irt}$ and profitability response $?_i$, we can then calculate the expected market shares for the first forecast year, and allocate supply and demand accordingly. Based upon the new allocation of supply and demand, and the estimated elasticity of substitution, we can calculate a complete and balanced set of trade flows for the first forecast year.

Then, we calculate the EXW price for each commodity, in each region, in the first forecast year, by using equation (6.11) and the value of $P_{\tilde{g}rt?1}$ as an estimate of $P_{\tilde{g}rt}$. Using the EXW price we have just calculated, we use equation (6.7) to calculate the delivered price $P_{g\tilde{r}rt}$ for every good g, and for every origin region $\tilde{r}$, and destination region r.

Using this estimate of delivered price, we calculate the price index for each good g, and region r, in the first forecast year using equation (6.10). Once all price indices have been updated, we can recalculate the complete menu of EXW prices, to recalculate a complete set of delivered prices, then recalculate all price indices. This process is repeated until it converges completely. Because each iteration is capturing prices across a greater number of regions, the process necessarily converges very quickly.

With the delivered price and price index data for all regions and goods for the first forecast year, we can calculate industry i profitability for all industries in all regions, using equation (6.15). Based upon the calculated profitability $?_{irt}$ and profitability response $?_{i}$, we calculate the expected market shares for the second forecast year, and allocate supply and demand accordingly. The whole process is then repeated for each and every year of the forecast period, to build a complete county level CGE model of United States Economy that is consistent with the new economic geography framework. The next section explores some of the basic properties of the resulting model/forecast.

Exploring Properties of the Dynamic CGE Model

Because of the switch from the SIC (Standard Industrial Classification) to NAICS (North American Industrial Classification System) system for coding industries and commodities that took place over the 1997-2000 time frame, and because the U.S. Bureau of Economic Analysis chose not to collect data in both formats for a single overlapping year, there exists no technique that will generate even a remotely useful county level time series that overlaps the two coding systems (Tanner & Hearn, 2005). Because the model we have developed ultimately is to be applied to regional planning activity, it has been built entirely in NAICS, which means that the data series cannot be extended before 1999. As such, the model is constructed using a complete historical database that covers only the years 1999-2001. The major shortcoming of this arrangement is that the model's forecasting capability cannot yet be tested against historical data; the estimation of trade flows in chapter 2 requires two years of historical data, and that leaves a measly one year of historical data that could be used to test the model. This is clearly insufficient to test a structural model. So, as in chapter 4, we are left to explore characteristics of the model forecast, while having to rely upon the integrity of the model logic, as opposed to its historical performance.

Because the model forecasts an enormous number of concepts, identifying data that will capture the overarching concepts of the New Economic Geography framework is a challenge. The challenge is intensified by the fact that the model forecasts the market share accruing to each county in every market, and hence, the U.S. aggregate forecast tells us nothing about the nature of the regional model. Because the NEG model is fundamentally driven by market shares and the amount of land available, it seems the single metric that best captures the model behavior is "relative total industry output per acre." That is, the total amount of output per acre in a county, relative to the total amount of output per acre in the United States. By this metric, a county with a relative total industry output per acre of 1, is producing exactly as much per acre as the U.S. as a whole. A county with a metric greater than 1 is, to some degree, a core county, and a county with a metric smaller than one is, to some degree, a periphery county. If the metric for a county is increasing over time, this would reflect a county that is experiencing economic agglomeration, and if the metric is decreasing over time, this would reflect a county dominated by dispersion forces.

To provide a frame of reference, in 2002 the "most peripheral" county in the United States was the Yukon-Koyukuk Census Area in Alaska. With a relative output per acre measure of 0.00031, this region had an "economic density" that was $31/100{,}000$ of the national average. By this same metric, the five "most peripheral" counties in the United States in 2001 were: Yukon-Koyukuk Census Area, Alaska, Lake and Peninsula Borough, Alaska, Loving County, Texas, Petroleum County, Montana, and Yakutat City and Borough, Alaska.

At the other extreme, the most economically dense (or "most core") county in the United States was New York County, New York, with a relative economic density of 5803.38, meaning that output per acre in New York County is over 5800 times the national average output per acre. The top five “most core counties in the United States in 2001 were: New York County, New York, San Francisco County, California, Suffolk County, Massachusetts, the District of Columbia, and Arlington, Virginia.

Under this measure of economic density, using what we know of the new economic geography structure of the model, we can begin to picture how various counties might be forecast to behave within this structure. We would expect that periphery regions like Yukon-Koyukuk, are likely to be very stable periphery counties, and that they are likely to see very little change in their economic density over time. Likewise, we might expect the “most core” regions, like New York County, will be relatively stable in their market share. Between these two extremes, we have an array of regions that might, over the forecast period, be moving toward “greater coreness” or “greater peripheriness” if they are near their break point (another term introduced in the previous chapter). And we might have yet another group of midsize regions that are losing there “coreness” or “peripheryness” as they pass the sustain point for their particular equilibrium. If we look at the behavior of these counties in the aggregate, we expect to see a number of counties that are stable within their core, periphery, or dispersed equilibrium, and some counties that, across the forecast period, will be making the transition from core or periphery. We have compared our forecast to two alternative, naïve forecasts, and we see a result that is largely as expected. The first alternative forecast assumes the county share of U.S. output to remain constant throughout the forecast period, and a second assumes that the county share of U.S. output will grow at the average annual rate exhibited in the 1999-2001 historical period. Both of these forecasts would be expected to correspond well with the counties that do not approach a break or sustain point. The constant growth forecast is expected to perform comparatively well over the short term with counties that are in transition, but will likely perform very poorly as those counties approach their new core or periphery position. The constant share forecast will not accurately reflect the counties while they are in transition, but will not be wildly incorrect over time, as those counties approach their new equilibrium and settle into a more-or-less fixed output share. By examination of the correlation coefficients over the forecast period between our model, the constant shares model, and the constant growth model, we see results consistent with our intuition (see figure 6.1) For the first fifteen to twenty years of the forecast period, the forecasts of county level relative output per acre are very tightly correlated among the three forecast types. The correlation of the model forecast with the constant share forecast then begins to drop off, and by the close of the forecast period, the correlation between the constant growth forecast and the NEG model forecast is virtually zero. This is consistent with the idea that counties that are experiencing share growth are in transition, and not exhibiting a permanent relative growth behavior as suggested by the naïve model.

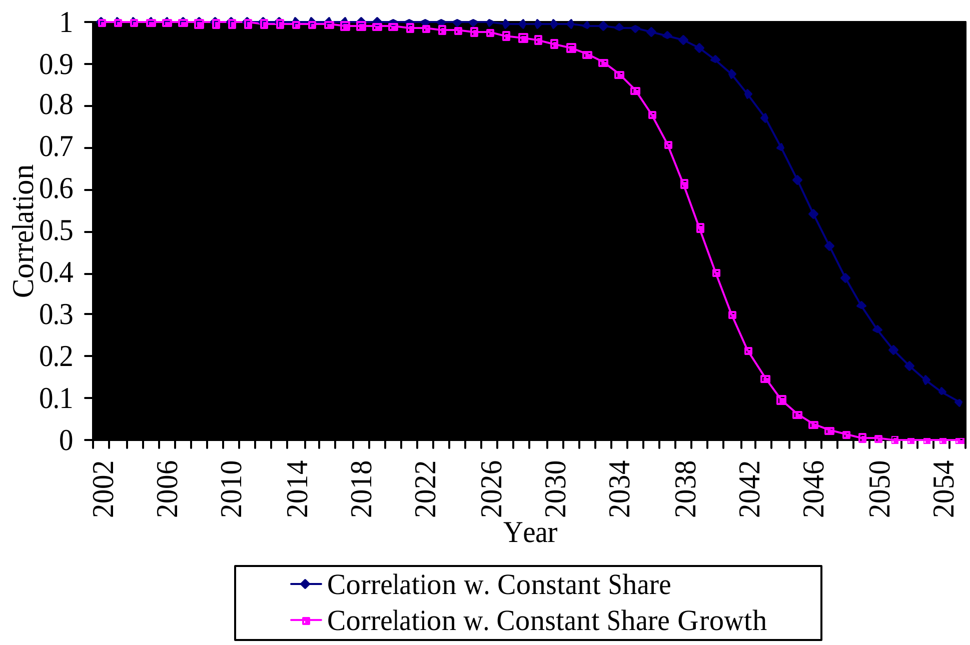

Figure 6.1: Correlation of the NEG model with the constant output share and constant output growth models.

The constant share forecast is much more tightly correlated with the NEG model forecast, for a much longer period of time. By the close of the forecast period, there is still approximately 9%

correlation between the constant shares forecast and the NEG model forecast. Once again, this is consistent with our intuition regarding market behavior in an NEG format.

We can capture this behavior in another way, by looking at the behavior of our chosen metric, relative output per acre, within deciles. With a total of 3,110 counties, each year we divide these counties into ten groups of 311, based upon their relative output per acre. The 311 counties in the smallest decile are, in a sense, the "most peripheral," and the 311 in the largest decile are the "most core." Because our metric is a county aggregate, it necessarily abstracts from the more in depth model behavior, since every industry, in every county, can have any degree of "coreness" or "peripheryness." Nonetheless, if we expect that movement toward core and periphery solutions fundamentally drive the economy, we can expect some specific behaviors to appear in the data. In an economy moving toward increasing heterogeneity, we would expect the average growth rate in the very smallest regions to be either constant (if they are as peripheral as they can get) or shrinking, and the growth rate of the very largest regions to be, in general, either constant (if they have reached a point of maximum "coreness") or growing. Somewhere in the middle of the distribution, we might expect to see counties that are in transition to a core position, or perhaps to a periphery position. A look at the growth rates by decile in Table 6.1 reveals some interesting patterns. First, the relative output of the smallest 311 counties is shrinking, and is shrinking slightly faster than it is for any other decile. Deciles 2 through 6 are shrinking slightly as well, though each successive decile is shrinking slightly less. The 622 regions in deciles 8 and 9 are actually growing in share of U.S. output, suggesting that they are moving toward becoming cores. The largest 311 regions, however, are exhibiting almost no growth in share of U.S. output, suggesting that the most core U.S. counties simply cannot get any more "core" than they already are. These counties are likely running into the model barrier created by land prices, which simply precludes further agglomeration.

Table 6.1: County relative growth in share of US output, by decile, 2002-2055.

Decile	Average Growth Rate	Decile	Average Growth Rate
Smallest	0.9814	6	0.9990
2	0.9883	7	0.9995
3	0.9913	8	1.0045
4	0.9923	9	1.0074
5	0.9950	Largest	1.0002

The Evolution of Core and Periphery in the Applied CGE Model

A microcosm of the movement form periphery to core can be found within a major metropolitan area, by examining a cross section of counties within the metropolitan area. If we were to start in downtown Atlanta, and travel due north, we would start in very urban Fulton County (relative output/acre in 2001 of 54.0), through the urbanizing Cobb County (relative output/acre in 2001 of 27.8), through the suburban county of Cherokee (relative output/acre in 2001 of 1.7), though the "exurban" county of Pickens (relative output/acre in 2001 of .5, and out of the Atlanta MSA into the rural counties of Gilmer and Fannin (relative output/acre in 2001 of .3 and .2, respectively). Examining the forecast for these counties (see Figure 6.2) reveals an interesting pattern, and a pattern that can be found in several other fast growing MSAs.

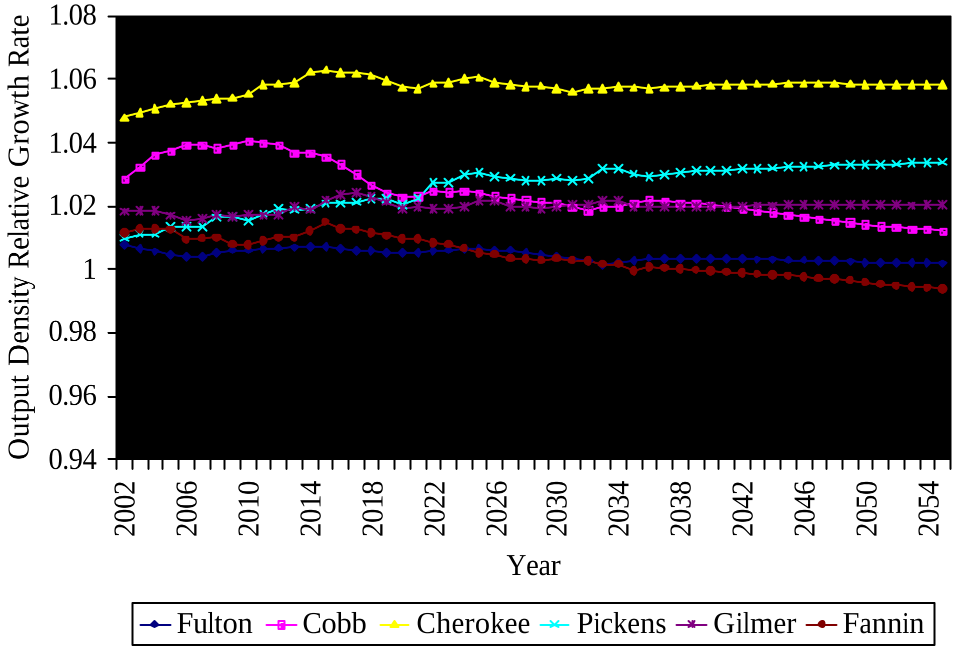

Figure 6.2: Forecast rate of relative growth in share of US output for a cross section of Atlanta counties.

The very urbanized Fulton County share of U.S. output is growing through the forecast period, though the rate for growth is slowing throughout the forecast period, as demonstrated by the generally downward sloping time series in Figure 6.2. This behavior seems to be typical of many of the "most core" counties in the model; these regions tend not to experience much growth (or decline) in share of U.S. output, as reflected earlier in Table 6.1. Cobb County, the next most urban county in our cross section, is experiencing comparatively rapid growth in output share for the first several years of the forecast, but the rate of output share growth begins to decline dramatically around the year 2010. It should be noted that Cobb County is both very close to Atlanta, and very much smaller (geographically) than is Fulton County itself, so land prices are relatively more dynamic in Cobb than in Fulton. The next county out, Cherokee, exhibits very strong growth in output share, and that growth remains relatively constant throughout the forecast period. Pickens County, the next county north from downtown Atlanta, shows a very modest rate of growth in output share in the first years of the forecast, but growth in output share for Pickens County increases dramatically throughout the forecast period. Next, we have the largely rural Gilmer County. Like the other counties in our cross section, Gilmer County is seeing some growth in output share throughout the forecast period; however, the rate at which output share is increasing is only very minute throughout the forecast period. At the very outer edge of our cross section lies Fannin County. Fannin is forecast to experience a modest growth in share of U.S. output through the first several forecast years. However, the rate of growth of output share is declining. As a result, by 2035 Fannin is forecast to begin experiencing a decline in share of U.S. output, as it is evidently not sharing in the overall growth of the Atlanta region, as we see manifest in the other counties.

What we are seeing in this geographic cross section of a major MSA, is a much more complex version of the theoretical process of generating a core and periphery in our two region model in chapter 5. A completely core county (like Fulton) remains relatively stable with respect to share of multi-region output. But other counties might be hovering on the brink of the break point (like Cobb, Cherokee, Pickens, and Gilmer) and have, at various points in time in the past, been “falling into” the core. Cobb is in the latter stages of the fall into the core, and is evolving toward a fully mature core county, with a stable, but very large amount of output. Cherokee is in the middle of its “growth spurt” as it moves to the core, and Pickens is just beginning to move into its period of rapid acceleration into a core economy. Gilmer, on the other hand, seems to be continuing to walk the fine line between the core and the periphery throughout the forecast period. Finally, our very rural Fannin County appears to be “falling into” the periphery, losing output share at the same time that our other counties are gaining market share. Once again, even though we are examining only three individual counties, recall that these counties are aggregates of the behavior of all of their various industries, and that these counties are also operating within our full 3,110-region framework, so this description is an abstraction designed to highlight the most fundamental forces at work on these economies.

Agglomeration from a Homogeneous Economy

At this point, we have seen that the model will tend to generate core/periphery economies once they are presented with a heterogeneous economy as a starting point; in this case, we started the model with our clearly heterogeneous 2001 economy, and allowed the model to go from there. However, it might be interesting to test whether the model can develop a heterogeneous economy from a completely homogeneous starting point, and what characteristics this artificial economy might have. To that end, the forecasting model was adjusted in a few fundamental ways. First, the input-output matrix, which evolves over time in the forecasting model, is "locked down" as the 2001 input-output matrix, which means that changes in production technology will not take place, so the economy is evolving toward some fixed equilibrium, rather than an equilibrium that is, itself, changing due to input-output changes. Secondly, the total US output for every industry in the model was spread evenly across every county, in proportion to each county's share of total U.S. land area. So, a county that represents .1% of U.S. land area also was assigned .1% of total U.S. output of every industry. Thus, the model was starting from a truly dispersed "backyard capitalism" scenario.

With this starting point, a total of five alternative model specifications were built. In the first model specification, first difference values A_{gr} were set to 1 for all goods in all regions. That is, the model assumed that there were no first nature differences for any production activity in any region (so, coal mines, for example, could be located anywhere). Second, all impedance values, for all modes, for every region-region combination were set to 1. This means that there was also no transportation related advantage for any region in the model; any region would produce their output and sell it in every region (including there own) for the same price. All other characteristics of the model were left unchanged. This model was then allowed to run through 54 simulated years. It should come as absolutely no surprise that, under these restrictions, no agglomeration whatsoever takes place. The economy at the end of the 54 cycles remains completely homogeneous for the simple reason that, with no first nature price differences and no potential for second nature differences, there is no force to encourage any movement from the dispersed equilibrium.

For the second scenario, we reintroduce the first difference values A_{gr}, that were calculated for the model, but we continued to allow all goods to be shipped from any region, to any region, for the same price. This model effectively allows for first nature differences, but removes all second nature differences. When this model was allowed to cycle through 54 years, the result was spectacular agglomeration; agglomeration that is much greater than that actually seen in the U.S. economy in 2001 (as measured by the standard deviation in county output per acre). The reason for the spectacular level of agglomeration is simply that, with transportation costs not entering into the picture, all economic activity is strongly attracted to the places with the greatest first nature advantage in production. Many activities that we intuitively know are significantly constrained by transportation (restaurants, gas stations, grocery stores) will, nonetheless, cluster in a relatively small number of counties, even if the first nature price advantage is small, simply because the transportation effect has been removed.

The next incarnation of the model again removed the first nature differences, but this time the impedance values for every mode of transportation was set to equal the straight line distance between county centroids. Internal distances for every region were set equal to the square root of the region's land area. Under this configuration, we are removing any first nature differences among regions, and allowing second nature differences, but those second nature differences use the simplifying assumption that transportation costs are simply proportional to straight line distance. When this model is allowed to continue for 54 years, it generates economic agglomerations, though the agglomerations are much more modest than those created by the first nature difference model. The agglomeration is, of course, generated strictly through the second nature differences in this model.

The next incarnation of the model was very similar, except that the straight line distances were replaced with the Oak Ridge impedance data. Therefore, this model included all transportation infrastructure data for second nature differences, but still included no information about first nature differences. Not surprisingly, this model also generated economic agglomeration over the forecast period; the agglomeration was somewhat more pronounced then that generated by the straight line distance model, but still much less than the agglomeration generated by the first nature differences themselves. The agglomeration in this model is greater than that of the straight line distance model, simply because the transportation data is much more heterogeneous than the straight line distances. Two adjacent counties will face almost the same menu of straight line distances, and will, therefore, be almost equally preferable if that is the metric used for transportation costs. However, when a major highway, a rail line, and a port are located in one county and not the other, the difference between the two, from a profitability standpoint, becomes quite dramatic.

The final incarnation of the model included all of the transportation infrastructure data, and all of the first nature difference data. This version was simply the full model, but run on an initially homogenous distribution and with a constant IO table. This model exhibited somewhat more agglomeration than the model with transportation, but not first order differences. However, the model still showed much less agglomeration than the model of first nature differences alone.

The purpose of this experiment was not simply to look at the models compared to one another, but also to look at how the models might compare to the actual 2001 U.S. economy. We know that history matters, and that there are a near infinite number of potential equilibria in an NEG mode with this many regions and sectors. However, it seems reasonable that given the distribution of first nature differences, and given our heterogeneously distributed transportation infrastructure, we might gravitate to a similar spatial distribution of economic activity, even from very different starting points. In this case, we are taking our starting point of a homogeneous economy, with a fixed 2001 technology, and letting each of our alternative model specifications run for 54 years, to see how the resulting economy compares to the actual U.S. economy in 2001 (which obviously started from a very different starting point). Once again, we use our metric of relative output per acre for each county, and will see whether any of our model configurations are correlated with the actual 2001 economy. The summary results are reported in Table 6.2.

Table 6.2: The degree of correlation between the distribution of economic activity in the U.S. in 2001 and the distribution of economic activity 54 years removed from a homogeneous distribution, for various model configurations.

Forecast Method:	**Correlation with 2001 Output per County:**
No First Nature Difference	NA
First Nature Effect Only	.0593
Distance Effect Only	.1314
Transportation Effect Only	.5727
Transportation and First Nature Effects	.6502

The model with no first or second nature differences, of course, exhibits no heterogeneity at the end of 54 years, so there is no correlation to discuss. The model with first nature differences, but no transportation had a very high degree of agglomeration, but the agglomeration is only minimally correlated with the agglomeration in the actual economy. While the first nature model might perform very well for some industries, such as mining, which are clearly driven by location specific cost factors, it tells us little about industries that are more affected by market access, rather than by first nature differences.

The models that capture transportation (and hence shipping cost) are each much more strongly correlated with the actual U.S. 2001 data. The model that imbeds impedance data (but without first nature differences) generates a correlation of over 57%. Finally, the full model, with first nature differences and transportation infrastructure, manages to endogenously generate a heterogeneous economy that is over 65% correlated with the 2001 U.S. economy. These correlations are surprisingly high, and are no doubt driven largely by the fact that transportation generates economic agglomeration, which drives economic development, so the model is capturing the correlation between level of infrastructure and the size of the economy. In this way, the model is generating results very similar to Sutton, Roberts, Elvidge, and Meij (1997). They tested the simple correlation between the light levels from nighttime satellite photos of the United States, and the county level income data for the United States. Their analysis found a correlation of 84% to 93%, which is in line with the numbers found in this analysis.

While the exercise of building these alternative models has no immediate practical application, it is certainly reassuring to note the model's ability to spontaneously agglomerate a homogeneous economy in a manner consistent with NEG theory. In examining the degree of correlation between the model and the 2001 data, it also suggests a certain degree of inevitability in the specific pattern of heterogeneity observed in the U.S. economy.

While we do not yet have a sufficient historical record against which to test the model, these results can at least reassure us that the model is behaving as we would expect, given the theory.

Chapter 7

WHERE TO GO FROM HERE: INTRODUCING PROPOSED EXTENSIONS TO THE MODEL

Where to Go From Here

The thrust of this paper is less to define a complete and entirely self-contained research project, than to build the foundations of a larger research agenda. In chapter 2, we established, perhaps, the most fundamental concept in this paper, the reconfiguration of the traditional Input-Output tables and Social Accounting Matrix to define every market interaction as an explicit exchange of "commodities" between "industries." The merged IO-SAM, by being "economically complete" (explicitly representing every utility/profit maximizing transaction for all entities in the economy) provides a holistic framework within which we might develop a simple, but comprehensive, set of CGE equations, without resorting to any awkward or add-hoc modeling assumptions. In chapter 3, we outlined the convoluted process of completely populating the merged IO-SAM for all counties in the United States; this exercise has been done with varying degrees of success by others in the past. The innovative process of filling County Business Patterns through iterative narrowing of the range of suppressed data marks the most serious departure from the procedures followed by others. A similar process could readily be applied to the many other federal data series that provide range data for suppressed data points.

In Chapter 4, we explore the estimation of trade flows by means of a gravity equation with an explicit elasticity of substitution component. These elasticities and trade flows are essential to this economic model, and are the key to all models of regional economies; however, approaches used to estimate trade flows in the past have been woefully inadequate. Our approach, using panel data to track the co movement of supply and demand across regions over time, is a significant innovation for such trade flow analysis. In Chapter 5, we introduce a very simple set of behavioral assumptions from the new economic geography literature, that may be applied to the data structures we have developed to define a complete, and relatively elegant, applied new economic geography model structure. Finally, in chapter 6, we outline the steps taken to turn all of this theoretical and applied analysis into a dynamic, multi-region trade flow model of the United States economy. The resulting model represents a new direction for CGE modeling, and introduces a new tool to those who conduct applied economic impact analysis in the United States.

There is certainly potential to build on these initial modeling efforts. Some steps are relatively obvious and rely simply on adding more data. For example, the model structure could seamlessly be applied to more regions, allowing for the possibility of sub county modeling (perhaps using Bureau of Economic Analysis ZIP Business Patterns data to subdivide counties), or of regional economic modeling in a multinational framework. Other developments are enticing, but beyond the reach of the model at this point. The model could ultimately be applied to an agent based modeling framework, with the transaction behavior of individual traders explicitly modeled, and probabilistic and adaptive learning behavior based within this larger model framework. The model structure also opens up the possibility of modeling business cycle behavior as a natural result of temporal agglomeration – such temporal agglomeration seems a natural extension of the spatial agglomeration in the new economic geography literature, and might be integrated into such a model.

The thrust of this chapter is to outline extensions of the core model that are currently under development. It is hoped that these model extensions will further clarify the potential of the core model structure, and might inspire further, or parallel, model development by others. The key model development efforts outlined in this chapter include developing population and migration dynamics for the model, disaggregation of the labor industry into several occupations, and modeling the endogenous genesis of new industries in regional economies.

A Model of Domestic Labor Migration

The national forecast used in the economic model includes population data as an element of the data series. However, the regional modeling process does not rely in any way on regional population data; indeed, the regional forecast, as conceived to this point, has nothing to say about the population of regions. The absence of a population forecast is unique to this regional model, and is "caused," in a sense, by the fact that the model denominates all trade in terms of dollars, so, the number of people is beside the point.

That said, there is a great deal of (perceived) value in generating regional demographic forecasts, and the core model described to this point can be augmented to include a demographic component, without having to adjust the core model design in the slightest. The demographic forecast process proposed here will produce a highly disaggregated population forecast with a minimum of additional data sources, and the procedure will be entirely "post process." It will be driven entirely by the core economic forecast, but the economic forecast of the core model will remain entirely unaffected by the demographic component (the forecast to this point does not rely on demographic data, and there is no reason to change that now).

Two additional data sources are required to integrate a demographic forecast into the model. First is the U.S. Census Bureau Detailed National Population Projections to 2100. This data series projects total United States population by single year of age (a total of 101 age cohorts), gender (two cohorts), race (four cohorts), and Hispanic origin (two cohorts). This represents a total of 1010 different age/gender/race/ethnicity cohorts. The forecast gives population estimates for each year through 2100.

The second data series is the county level detailed population estimates, produced by the U.S. Census Bureau for (and available through) the Center for Disease Control National Center for Health Statistics. The data gives estimates of the resident population of all counties in the United States by single year of age (0, 1, 2, ..., 84, 85 and over), gender (male, female), race (White; Black; American Indian and Alaska Native; Asian and Pacific Islander) and Hispanic origin (Hispanic origin, non-Hispanic origin) for July 1, 1990 through July 1, 2003. Note that the local area population estimates include 15 fewer age cohorts (a total of 860 age/race/ethnicity/gender cohorts), but otherwise represents the same disaggregation found in the U.S. Census Bureau national population projections.

The population estimates for both of these data series are developed using a cohort-component method, whereby each component of population change - births, deaths, domestic migration, and international migration is estimated separately for each birth cohort by sex, race, and Hispanic origin. The cohort-component method is based on the traditional demographic accounting system:

$$Pop_{crt?1} \; ? \; Pop_{crt} \; ? \; Deaths_{crt} \; ? \; Births_{crt} \; ? \; \overset{R}{\underset{\tilde{r}?1}{?}} Mig_{c\tilde{r}rt} \; ? \; Mig_{cROWrt} \qquad (7.1)$$

where $Pop_{crt?1}$ is the population of cohort c in region r at time $t ? 1$, and Pop_{crt} is the population of cohort c (the same gender/race/ethnicity, one year younger) in region r at time t. $Deaths_{crt}$ and $Births_{crt}$ are the number of deaths and births for cohort c in region r at time t (a function of the mortality and fatality rate for the cohort in the region). Finally, $Mig_{c\tilde{r}rt}$ and Mig_{cROWrt} are, respectively, the migration of cohort c from region $\tilde{r}$, and from the rest of the world (ROW), to region r at time t. To generate population estimates, separate data sets are integrated for each of these components. Once the data for each component is developed, the estimates for each cohort, region, and year are produced simply by adding the components together.

The population distribution across regions within the United States is, presumably, driven by the same forces that drive the firm location decision – that is, the relative profitability of the "labor industry" will drive the migration of people and by extension, the births, deaths, and international migration of all of the various cohorts in the model. As such, we would propose estimating the regional population (by cohort) via a simple OLS estimation of the equation:

$$\frac{Pop_{crt?1}}{\sum_{\tilde{r}?1}^{R} Pop_{crt?1}} ? ?_{c} ? ?_{cr} ? ?_{ct} ? ?_{Popct} \frac{Pop_{crt}}{\sum_{\tilde{r}?1}^{R} Pop_{crt}} ? \sum_{t?t?n}^{t?m} \left(?_{?ct} \frac{?_{irt}}{\sum_{\tilde{r}?1}^{R} ?_{irt}} \right) \qquad (7.2)$$

where $Pop_{crt?1}$ is the population of cohort c in region r at time $t ? 1$. $?_{c}$, $?_{cr}$, $?_{ct}$, are, respectively, the constant for the OLS, a regional fixed effect, and a cohort specific time trend. $?_{Popct}$ and $?_{irt}$ are the OLS coefficients on the lagged population share variable and the regional relative profitability variable(s) in the model. Pop_{crt} is the population of cohort c in region r at time t. $?_{irt}$ is the profitability of the labor industry i in region r at time t. $t ? n$ and $t ? m$ reflect the number of lagged (n) and leading (m) time periods, where the profitability measure is used.

It is anticipated that the time trend $?_{cr}$ is likely to be insignificant (this variable would be significant, only if there is a significant increase or decrease in the migration/mobility of a cohort over time), but the regional constant $?_{ct}$ is likely to play a significant role for many cohorts and regions. With this simple population equation, the regional constant will capture population specific "noneconomic" factors, including the relative immobility of certain cohorts in, for example, counties with large prisons or universities (populations that are unlikely to migrate in response to economic stimuli). The regional constant is also expected to catch relative resistance to migration that might be found in native reservations, rural communities, international migrant communities, etc.

Because of the tremendous disruption and expense that is associated with population migration between regions, we can expect that population changes are likely going to be associated with several years of profit signals. Ordinarily, regional models rely strictly upon lagged migration signals (as we propose for $t ? n$ time periods) in an adaptive expectations assumption. One strength of calculating population only after the economic forecast is complete, is that we are able to estimate the population response for up to $t ? m$ *leading* profitability variables, as warranted by the data. This means that we can essentially develop a regional population model built upon an assumption of rational, rather than adaptive expectations.

A Model of Labor Agglomeration

One area of the model that is particularly suited to serious improvement is the modeling of the labor industry. Under the current model configuration, labor is a single, undifferentiated industry; the elasticity of substitution within the labor industry allows for distinction among individual labor "firms," but this is clearly an undesirable simplification. One would expect that labor is better represented as a number of "industries" (occupations), where the individual occupations might have quite different elasticities of substitution. A priori, one might expect that unskilled labor occupations generally face a very high elasticity of substitution, while higher skilled occupations likely face significantly lower elasticities of substitution. Thankfully, the data resources are available to draw distinctions among the various occupations, potentially to a very high level of occupational detail.

Two additional data sources must be integrated into the current model structure in order to distinguish occupations within the labor industry: the Bureau of Labor Statistics National Industry-Occupation Employment Matrix and the Census Journey to Work and Place of Work Data. The BLS Industry Occupation Matrix is very similar to the 2002-2012 BLS Make and Use Matrices described in chapter 3. The National Industry-Occupation Employment Matrix is developed by the Bureau of Labor Statistics as part of its ongoing Occupational Employment Projections Program. Data from the

2002-12 matrices underlie information on occupational employment growth presented in the 2004-05 Occupational Outlook Handbook and Career Guide to Industries. The 2002 matrix was developed primarily from the Occupational Employment Statistics survey, the Current Employment Statistics survey, and the Current Population Survey. The 2012 matrix was developed as part of the BLS occupational employment projections. The 2002-2012 National Employment Matrix presents employment for 284 detailed industries and 725 detailed occupations following the occupation definitions of the 2000 Standard Occupational Classification (SOC) system. As such, the methodology outlined here could be used to discover elasticities of substitution among up to 725 different labor "industries," representing potential for significant improvement over the single labor industry outlined to this point.

In estimating the elasticity of substitution for industries in chapter 5, we used panel data on the location of industry supply and the location of industry demand to calculate elasticities of substitution for each industry, and by extension to determine the trade flow linkages among all industries and all counties in the U.S. In disaggregating the labor industry into several occupations, we can use the industry occupation matrix to determine labor demand by occupation for every county. However, we have no information that allows us to define the location of occupation supply by county (as we have from the make matrix in the IO tables). Therefore, we need an alternative approach to estimate elasticity of substitution and trade flows by occupation.

One proposed estimation procedure involves taking full advantage of the census journey to work data, available in full detail only for census years. This data series, described in chapter 3, details the total wages earned for every county of work and county of residence in the United States (that is, it identifies the total wages paid in every county in the US, by county of residence). Presuming that the various occupations (at whatever level of dissagregation proves desirable) each face a (potentially) unique elasticity of substitution, while each face the same transportation impedances between regions, we can take advantage of regional differences in labor force composition and commuting impedance to estimate elasticities of substitution by occupation. In chapter 5, we showed that the trade flow between regions r and $\tilde{r}$ for commodity g is given by:

$$T_{g\tilde{r}rt} = \frac{Q_{g\tilde{r}t} \cdot A_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\varepsilon_g}}{\sum_{\tilde{r}=1}^{R} \left(Q_{g\tilde{r}t} \cdot A_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\varepsilon_g} \right)} \cdot D_{grt} \qquad (7.3)$$

where $T_{g\tilde{r}rt}$ is the quantity of good (i.e., occupation) g produced in region $\tilde{r}$ and sold in region r, in time t. $Q_{g\tilde{r}t}$ is the total quantity of good g produced in region $\tilde{r}$ in time t, D_{grt} is the total quantity of good g demanded in region r in time t, and $P_{g\tilde{r}rt}$ is the sales price of good g produced in region $\tilde{r}$ and sold in region r at time t. Finally, $A_{g\tilde{r}t}$ is the regional balancing factor for good g produced in region $\tilde{r}$ in time t, ε_g is the own price elasticity of good g, and R is the total number of regions.

As we have already discussed, this same trade flow relationship would hold for all labor "industries" (occupations). While we have no information about the trade flows between regions by occupation, we do know the aggregate trade flows for all occupations, as given by the census journey to work data. If we make the simplifying assumption that the region's share of total labor within each specific occupation is approximated by the region's share of total labor, or:

$$\frac{\left(\sum_{g=1}^{L} Q_{g\tilde{r}t} \right)}{\sum_{\tilde{r}=1}^{R} \left(\sum_{g=1}^{L} Q_{g\tilde{r}t} \right)} \qquad (7.4)$$

then, we can approximate the aggregate trade flow for all occupations as:

$$\sum_{g=1}^{L} T_{g\tilde{r}rt} = \sum_{g=1}^{L} \left[\frac{\left(\sum_{g=1}^{L} Q_{g\tilde{r}t} \right) \cdot A_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\varepsilon_g}}{\sum_{\tilde{r}=1}^{R} \left(\left(\sum_{g=1}^{L} Q_{g\tilde{r}t} \right) \cdot A_{g\tilde{r}t} \cdot P_{g\tilde{r}rt}^{-\varepsilon_g} \right)} \cdot D_{grt} \right] \qquad (7.5)$$

where L is the number of distinct occupations to be estimated in the model. The data sources already in use in the model already identify all elements of the function except $?_g$, the own price elasticity of good (occupation) g. Equation (7.16) may be estimated by nonlinear least squares, in much the same way as was outlined for other commodities in chapter 5. Occupations may be defined in as much detail as is allowed by the industry occupation matrix (725 labor commodities), or as is suggested by the statistical significance of the estimated elasticities at various levels of occupational detail.

The "Immaculate Conception of Industries" CGE with Endogenous Introduction/Removal of Industries

In the previous section, we outline how to turn the IO model, outlined in the previous two chapters, into a simple CGE model with the agglomeration dynamics typical to New Economic Geography. Industries in the various regions may expand or contract as the agglomeration force (transportation costs, of both inputs and outputs) and the dispersionary force (land prices) interact dynamically, over time, with the location decisions of profit maximizing firms. One factor that has not yet been explored, and indeed has never been explored in any of the widely used regional economic modeling tools, is the birth or death of industries in a region. Under the configuration outlined above, industries present in uncompetitive regions may whither, but they will never completely die (market shares will approach, but never reach, zero). Likewise, in regions that do not have an industry, but are potentially very competitive in that industry, the model would never allow for the possibility of the industry suddenly arising in the region. Obviously, predicting the appearance or disappearance of an industry in a region is a highly speculative game – subject as much to the personal whims of business owners and the fickle hand of fate, as to any other conditions. No doubt this is why regional economic modelers tend to avoid these questions. Nonetheless, this model does allow one to apply some theoretical and analytical rigor to the birth and death of industries in a region, and this might be worth exploring.

The model produces two variables that would clearly be central to defining the moment when an industry might disappear from a region – the relative profitability measure, and the measure of total market share. Clearly, as regions see a decrease in either or both of these measures, there is an increased risk that the industry will disappear from these regions entirely. Theoretical NEG models would identify a single firm size for each industry, which would be conducive to calculating precisely when the market share is too small to support even one firm at zero profits. However, in the real world, every industry type has firms in a wide variety of sizes, and the time lag response ($?_i$) to profitability signals suggests that nonprofitable firms may not disappear for some time.

Fortunately, our historical data on output by industry, by region, provides a useful data source for a straight probability estimation of the likelihood of an industry disappearing from a region. Using the historic output and demand data, and the derived profitability index $?_{irt}$ and market shares, it becomes possible to estimate a simple binomial logit model of the probability of an industry disappearing from a region:

$$X_{irt} ? \{1 ? e^{?? _{Xi} ? ?_{Xit} ?_{irt} ? ?_{Xit?1} ?_{irt?1} ?}\}^{?1} \qquad (7.6)$$

where X_{irt} represents the probability of industry i exiting region r at time t. This is a function of $?_{irt}$ (and potentially one or more lagged values $?_{irt?1}$), the profit of industry i in region r at time t. $?_{Xi}$, $?_{Xit}$, $?_{Xit?1}$ are the regression parameters for the logit model; note that more, or fewer, values of $?_{ir}$ may be appropriate; the precise number of lags can be determined at the time the regression analysis is performed.

If this seems a highly speculative process for identifying doomed industries, the estimation procedure for when an industry newly arises in a region is even more speculative, though it follows the same procedure using the same variables, on the same historical data. As with equation (7.1), spontaneous arrival of an industry may be estimated by the logit model:

$$E_{irt} ? \{1 ? e^{?(?_{Ei} ? ?_{Eit} ?_{irt} ? ?_{Eit?1} ?_{irt?1})}\}^{?1} \tag{7.7}$$

where E_{irt} represents the probability of industry i exiting region r at time t. This is a function of $?_{irt}$ (and potentially one or more lagged values, $?_{irt?1}$), the profit of industry i in region r at time t. $?_{Ei}$, $?_{Eit}$, $?_{Eit?1}$ are the regression parameters for the logit model; note that more, or fewer, values of $?_{ir}$ may be appropriate; the precise number of lags can be determined at the time the regression analysis is performed.

Clearly, the estimation procedures in (7.6) and (7.7) suffer from the censoring problem faced by all such equations, in so far as, market share is truncated at zero. However, the same cannot be said of the profitability index, if one is willing to make one additional calculation. Recall that the profitability index $?_{irt}$ for any industry in any region relied upon knowing both the trade flows from the region in all goods produced by industry i, and knowing the delivered price of every good to every region. Obviously, if an industry does not exist in a region, it is possible that all of the goods that the industry produces are not produced in the region (though all goods might be represented in the regions output, thanks to joint production). However, if we simply "artificially" introduce, say, $1 of output of any missing good into the price and trade flow equations, we can easily calculate what the trade flows and relative price of the good would have been. By extension, we can also calculate the profitability index, which in this case, reports how profitable the industry would have been in the region, had it existed. So, while the market share variable is censored at zero, the profitability index can be calculated for every industry in every region, even if the industry is not present in the region.

Once these probability functions are calculated, it is left to the model builder (or the individual using the model) to determine just how comfortable they are with speculating the addition or subtraction of industries; that is, a choice must be made about whether to include this data in the CGE model at all, and if so, to determine what probability threshold must be crossed to introduce or remove an industry from a region.

This extension of the model is extremely speculative, but it does afford an opportunity to gain insight into any number of questions of interest to regional economists. The "cluster effect," where attracting a few firms in an industry has led to a cluster of other firms in related industries , is intuitively appealing to many regions, and has gained a great deal of press; however, without much understanding of the dynamics at work. This sort of extension would create an endogenous "clustering effect" within the model, and might serve to shed light on this hot button topic, as well as others.

Conclusions

In this paper, we have integrated concepts, theories, and data from a number of different areas into a comprehensive regional economic modeling methodology. The case for using this approach to developing a computable general equilibrium model is (it is hoped) quite compelling, and it is felt that the model takes several important steps forward in the field of applied regional economic modeling, forecasting, and impact analysis. While the model development effort has been significant, what has been built to this point only scratches the surface of what might be possible, as additional data, computing power, and theoretical work makes ever more simple models that are capable of capturing ever more complex behaviors in an ever more accurate manner.

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Appendix A

FILLING REIS DATA SUPPRESSIONS

Introduction

All employment and income data in this model ultimately is made consistent with the Bureau of Economic Analysis' Regional Economic Information System (REIS) data series. This data set is the most inclusive and comprehensive regional data series available in the United States; it includes data on the Agriculture and State and Local Government sectors that are not available from other sources. The data series also provides county level data on self employment and proprietor income, and is designed to be consistent with the National Income and Product Accounts. The major drawback of the REIS data series is its low level of industry detail. Information on wages are only provided to the two digit level of industry detail at the state and county level, and employment are only provided to the two digit level of industry detail at the state level, and the one digit level of detail at the county level. Nonetheless, the data is perfectly suited to generate control totals for the County Business Patterns data series.

Just as with County Business Patterns, though, data suppressions in the REIS data must be filled before it can be used. To be usable, a complete series must be made for:

? 2 digit state level wage and salary income

? 2 digit state level wage and salary employment

? 2 digit state level total (wage and salary and self-employment) income

? 2 digit state level total employment

? 2 digit county level total (wage and salary and self-employment) income

? 1 digit county level total employment

Estimating a complete data series will require splitting a handful of regions apart that are currently treated as single regions in the REIS data series, and then deriving consistent estimates of suppressed data fields at the state and then the county levels.

Disaggregating Combined Regions in the REIS Data Series

County Business Patterns, and in fact most substate economic data series produced by the federal government, is available at the county level, meaning all counties in the United States, including all Alaska Administrative Zones, all Louisiana Parishes, and all Virginia Counties and Virginia Independent Cities. However, the REIS data series combines independent cities and adjacent counties, and in addition they report two Wisconsin counties as a single region up through 1994. These combined regions are identified in Table A.1.

Before any data suppression issues are addressed, these regions are simply split out into their component regions using the complete County Business Patterns employment and wage proportions for their component regions; in the case of the agriculture industries, these are shared out using the Census of Agriculture data.

Table A.1: REIS combined Cities and Counties

Region	CBP ID (FIPS)	REIS ID
Virginia		
Albemarle, Charlottesville	51003, 51540	901
Allegheny, Clifton Forge, Covington	51005, 51560, 51580	903
Augusta, Staunton, Waynesboro	51015, 51790, 51820	907
Bedford, Bedford City	51019, 51515	909
Campbell, Lynchburg	51031, 51680	911
Carroll, Galax	51035, 51640	913
Dinwiddie, Colonial Heights, Petersburg	51053, 51570, 51730	918
Fairfax, Fairfax City, Falls Church	51059, 51600, 51610	919
Frederick, Winchester	51069, 51840	921
Greensville, Emporia	51081, 51595	923
Halifax, South Boston	51083, 51780	925
Henry, Martinsville	51087, 51690	929
James City, Williamsburg	51095, 51830	931
Montgomery, Radford	51121, 51750	933
Pittsylvania, Danville	51143, 51590	939
Prince George, Hopewell	51149, 51670	941
Prince William, Manassas, Manassas Park	51153, 51683, 51685	942
Roanoke, Salem	51161, 51775	944
Rockbridge, Buena Vista, Lexington	51163, 51530, 51678	945
Rockingham, Harrisonburg	51165, 51660	947
Southampton, Franklin	51175, 51620	949
Spotsylvania, Fredericksburg	51177, 51630	951
Washington, Bristol	51191, 51520	953
Wise, Norton	51195, 51720	955
York, Poquoson	51199, 51735	958
Wisconsin		
Menominee, Shawano	55078, 5155115	901

Filling State Level Data Suppressions

The national level REIS employment and income data series is complete every year, and is disaggregates to the 2 digit level of industry detail. The state data series, however, has several suppressions for privacy reasons; the first step is to fill these data suppressions. The initial estimate of any suppressed wage and salary employment data points is the County Business Patterns total for that two digit industry. Once these initial estimates have been plugged in to every missing two digit wage and salary employment number for every state, the state values are RAS'ed, using Unites States data as control totals for the row elements, and one digit state REIS data as control totals for the column elements.

In some cases, estimating a two digit nondisclosure for total employment (wage and salary and self-employment) is trivial – in cases where a single nondisclosure at the 2 digit level of detail resides under a disclosed 1 digit total employment number, the undisclosed element can be filled accurately by simple subtraction. For nondisclosed total employment numbers that are not so trivially estimated, the first estimate is derived by calculating the national level self-employment to wage and salary employment for the industry sector. These estimates, too, are refined using a RAS with US data as the row totals and state level 1 digit total employment as the column totals; total employment is constrained at all times to be no less than the wage and salary employment already estimated.

The first estimate for wage and salary income at the state level is the state level County Business Patterns income/employment ratio, times the state wage and salary employment derived above. After plugging in all initial estimates, they are refined using a RAS with US data as the row totals and state level 1 digit total employment as the column totals.

The National Income and Product Accounts includes estimates of other labor income and wage and salary income for the United States, by sector. The NIPA ratio of other labor income to wage and salary income is applied REIS wage and salary income, as a first estimate of other labor income by sector. These estimates are then scaled to hit the total state other labor income in the REIS data series.

If the completed, RASed total employment table reports the same number of employees as does the wage and salary employment table, then there are no proprietor in that industry, and hence no proprietor income, so any suppressed total income cells that meet this criterion are filled the total of wage and salary and other labor income. For those cells where we are not so fortunate, a first estimate of the value of the suppression is made using the US ratio of proprietor to wage and salary income for the industry. Once these initial estimates have been plugged in to every missing two digit wage and salary employment number for every state, the state values are RAS'ed, using Unites States data as control totals for the row elements, and one digit state REIS data as control totals for the column elements.

Filling County Level Data Suppressions

Once state level suppressions are filled using the procedure described in the previous section, we can begin filling county level suppression using a complete state level REIS employment and income data series, disaggregated to the 2 digit level of industry detail. The initial estimate of any suppressed wage and salary plus self employment data points at the 1 digit level is calculated using the County Business Patterns county level share of total state employment for that 1 digit industry, times the total state employment already calculated for the industry. Once these initial estimates have been plugged in to every missing on 1 digit total employment number for every county in a state, the county values are RAS'ed, using state total data as control totals for the row elements, and total county employment REIS data as control for the column elements.

The initial estimate of any suppressed wage and salary plus self employment data points at the 2 digit level is calculated using the County Business Patterns county level share of total state employment for that 2 digit industry, times the total state employment already calculated for the industry. Once these initial estimates have been plugged in to every missing 2 digit total employment number for every county in a state, the county values are RAS'ed, using state 2 digit total employment data as control totals for the row elements, and total 1 digit county employment REIS data as a control for the column elements. Wage and salary employment for each industry at the county level is assumed to be the same proportion of total employment in that industry in that county as it is in that industry in the state.

Earnings per wage and salary worker by industry by county is calculated using the 2 digit County Business Patterns data, applied to the wage and salary employment data derived above. Other labor income is derived using the state level other labor income to wage and salary income ration from the state data, applied to estimated local wage and salary income. Finally, proprietor income is derived using state level income per proprietor. There are a small number of cases where no wage or salary employees exist in an industry in a county, but there are proprietors implied by the data because a total 2 digit income value is reported. In these cases, the number of workers is calculated based upon the income value times the state level income per worker.

Thus, a complete, internally consistent set of REIS data is derived for every locality for every year.

Appendix B

THE MACROECONOMIC MODEL

Introduction

The data that pertain to the US model are presented in this appendix. Table B.1 presents the six sectors in the US model: household (h), firm (f), financial (b), foreign (r), federal government (g), and state and local government (s). In order to account for the flow of funds among these sectors and for their balance-sheet constraints, the U.S. Flow of Funds Accounts (FFA) and the U.S. National Income and Product Accounts (NIPA) must be linked. Many of the identities in the US model are concerned with this linkage. Table B.1 shows how the six sectors in the US model are related to the sectors in the FFA. The notation on the right side of this table (H1, FA, etc.) is used in Table B.5 in the description of the FFA data. Table B.2 lists all the variables in the US model in alphabetical order, and tables B.3 and B.4 list all the stochastic equations and identities, respectively. Tables B.5, B.6 and B.7 show all data brought into the basic model from NIPA, and FFA, and all other data sources. Finally, table B.8 shows how the calculated variables were constructed from the raw data.

The National Income and Product Accounts and the Flow of Funds Accounts

The variables from the National Income and Product Accounts (NIPA) are presented first in Table B.5, in the order in which they appear in the Survey of Current Business. The Bureau of Economic Analysis (BEA) now uses "chain-type weights" in the construction of real magnitudes, and the data based on these weights have been used here. Because of the use of the chain-type weights, real GDP is not the sum of its real components. To handle this, a discrepancy variable, denoted

STATP, was created, which is the difference between real GDP and the sum of its real components. (STATP is constructed using equation 83 in Table B.3.) STATP is small in magnitude, and it is taken to be exogenous in the model. The variables from the model's other main data source, the Flow of Funds Accounts (FFA) are presented next in table B.6, ordered by their code numbers. Some of these variables are NIPA variables that are not published in the Survey of Current Business but that are needed to link the two accounts.

The Other Data

Interest rate variables are presented next in the table, followed by employment and population variables. The source for the interest rate data is the website of the Board of Governors of the Federal Reserve System (BOG). The source for the employment and population data is the Bureau of Labor Statistics (BLS). Some of the employment data are unpublished data from the BLS, and these are indicated as such in the table. Data on the armed forces are not published by the BLS, and these data were computed from population data from the U.S. Census Bureau. The list of non-NIPA, non-FFA variables are found on table B.7, and key adjustments that are made to the raw data are presented next in Table B.8.

Adjustments to the Raw Data

The adjustments that were made to the raw data are as follows. The quarterly social insurance variables R249–R254 were constructed from the annual variables R78-R83 and the quarterly variables R40, R60, and R71. Only annual data are available on the breakdown of social insurance contributions between the federal and the state and local governments with respect to the categories "personal," "government employer," and "other employer." It is thus necessary to construct the quarterly variables using the annual data. It is implicitly assumed in this construction that as employers, state and local governments do not contribute to the federal government and vice versa. The constructed tax variables R255 and R256 pertain to the breakdown of corporate profit taxes of the financial sector between federal and state and local. Data on this breakdown do not exist. It is implicitly assumed in this construction that the breakdown is the same as it is for the total corporate sector. The quarterly variable R257, INTPRI, which is the level of net interest payments of sole proprietorships and partnerships, is constructed from the annual variable R86, INTPRIA, and the quarterly and annual data on PII, personal interest income, R53. Quarterly data on net interest payments of sole proprietorships and partnerships do not exist. It is implicitly assumed in the construction of the quarterly data that the quarterly pattern of the level of interest payments of sole proprietorships and partnerships is the same as the quarterly pattern of personal interest income. The quarterly variable R258, INTROW, which is the level of net interest payments of the rest of the world, is constructed from the annual variable R87, INTROWA, and the quarterly and annual data on PII, personal interest income, R53. Quarterly data on net interest payments of the rest of the world do not exist. It is implicitly assumed in the construction of the quarterly data that the quarterly pattern of the level of interest payments of the rest of the world is the same as the quarterly pattern of personal interest income. The tax variables R57 and R62 were adjusted to account for the tax surcharge of 1968:3-1970:3 and the tax rebate of 1975:2. The tax surcharge and the tax rebate were taken out of personal income taxes (TPG) and put into personal transfer payments (TRGH). The tax surcharge numbers were taken from Okun (1971), Table 1, p. 171. The tax rebate was 7.8 billion dollars at a quarterly rate. The employment and population data from the BLS are rebenchmarked from time to time, and the past data are not adjusted to the new benchmarks. Presented next in Table A.5 are the adjustments that were made to obtain consistent series. These adjustments take the form of various "multiplication factors" for the old data. For the period in question and for a particular variable the old data are multiplied by the relevant multiplication factor to create data for use in the model. The variables TPOP90 andTPOP99 listed in table B.8 are used to phase out multiplication factors. Table B.4 presents the balance-sheet constraints that the data satisfy. The variables in this table are raw data variables. The equations in the table provide the main checks on the collection of the data. If any of the checks are not met, one or more errors have been made in the collection process. Although the checks in the table may look easy, considerable work is involved in having them met. All the receipts from sector i to sector j must be determined for all i and j (i and j run from 1 through 6).

Table B.1: The Six Sectors of the US Model

Sector	Corresponding Sector(s) in the Flow of Funds Accounts
1 Household (h)	1 Households and Nonprofit Organizations (H)
2 Firm (f)	2a Nonfarm Nonfinancial Corporate Business (F1) 2b Nonfarm Noncorporate Business (NN) 2c Farm Business (FA)
3 Financial (b)	3a Commercial Banking (B1): (1) U.S.-Chartered Commercial Banks (2) Foreign Banking Offices in U.S. (3) Bank Holding Companies (4) Banks in U.S.-Affiliated Areas 3b Private Nonbank Financial Institutions (B2): (1) Savings Institutions (2) Credit Unions (3) Bank Personal Trusts and Estates (4) Life Insurance Compan ies (5) Other Insurance Companies (6) Private Pension Funds (7) State and Local Government Employee Retirement Funds (8) Money Market Mutual Funds (9) Mutual Funds (10) Closed-End Funds (11) Issuers of Asset-Backed Securities (12) Finance Companies (13) Mortgage Companies (14) Real Estate Investment Trusts (15) Security Brokers and Dealers (1) (16) Funding Corporations
4 Foreign (r)	4 Rest of theWorld (R)
5 Fed. Gov. (g)	5a Federal Government (US) 5b Government-Sponsored Enterprises (CA) 5c Federally Related Mortgage Pools 5d Monetary Authority (MA)
6 S & L Gov. (s)	6 State and Local Governments (S)

Table B.2: The Variables in the US Model in Alphabetical Order

Variable	Eq.	Description
AA	89	Total net wealth, h, B96$.
AB	73	Net financial assets, b, B$.
AF	70	Net financial assets, f, B$.
AG	77	Net financial assets, g, B$.
*AG*1	exog	Percent of 16+ population 26-55 minus percent 16-25.
*AG*2	exog	Percent of 16+ population 56-65 minus percent 16-25.
*AG*3	exog	Percent of 16+ population 66+ minus percent 16-25.
AH	66	Net financial assets, h, B$.
AR	75	Net financial assets, r, B$.
AS	79	Net financial assets, s, B$.
BO	22	Bank borrowing from the Fed, B$.
BR	57	Total bank reserves, B$.
CCB	exog	Capital consumption, b, B96$.
CCF	21	Capital consumption, f, B$.
CCG	exog	Capital consumption, g, B$.

Variable	Eq.	Description
CCH	exog	Capital consumption, h, B$.
CCS	exog	Capital consumption, s, B$.
CD	3	Consumer expenditures for durable goods, B96$.
CDA	exog	Peak to peak interpolation of CD/POP.
CF	68	Cash flow, f, B$.
CG	25	Capital gains(+) or losses(-) on the financial assets of h, B$.
CN	2	Consumer expenditures for nondurable goods, B96$.
COG	exog	Purchases of consumption and investment goods, g, B96$.
COS	exog	Purchases of consumption and investment goods, s, B96$.
CS	1	Consumer expenditures for services, B96$.
CUR	26	Currency held outside banks, B$.
D1G	exog	Personal income tax parameter, g.
D1GM	90	Marginal personal income tax rate, g.
D1S	exog	Personal income tax parameter, s.
D1SM	91	Marginal personal income tax rate, s.
D2G	exog	Profit tax rate, g.
D2S	exog	Profit tax rate, s.
D3G	exog	Indirect business tax rate, g.
D3S	exog	Indirect business tax rate, s.
D4G	exog	Employee social security tax rate, g.
D5G	exog	Employer social security tax rate, g.
*D*593	exog	1 in 1959:3; 0 otherwise.
*D*594	exog	1 in 1959:4; 0 otherwise.
*D*601	exog	1 in 1960:1; 0 otherwise.
*D*621	exog	1 in 1962:1; 0 otherwise.
*D*692	exog	1 in 1969:2; 0 otherwise.
*D*714	exog	1 in 1971:4; 0 otherwise.
*D*721	exog	1 in 1972:1; 0 otherwise.
*D*722	exog	1 in 1972:2; 0 otherwise.
*D*723	exog	1 in 1972:3; 0 otherwise.
*D*794823	exog	1 in 1979:4-1982:3; 0 otherwise.
*D*923	exog	1 in 1992:3; 0 otherwise.
*D*924	exog	1 in 1992:4; 0 otherwise.
*D*941	exog	1 in 1994:1; 0 otherwise.
*D*942	exog	1 in 1994:2; 0 otherwise.
*D*981	exog	1 in 1998:1; 0 otherwise.
*D*013	exog	1 in 2001:3; 0 otherwise.
*D*014	exog	1 in 2001:4; 0 otherwise.
DB	exog	Dividends paid, b, B$.
DELD	exog	Physical depreciation rate of the stock of durable goods, rate per quarter.
DELH	exog	Physical depreciation rate of the stock of housing, rate per quarter.
DELK	exog	Physical depreciation rate of the stock of capital, rate per quarter.
DF	18	Dividends paid, f, B$.
DISB	exog	Discrepancy for b, B$.
DISBA	exog	Discrepancy between NIPA and FFA data on capital consumption, nonfinancial corporate business, B$.
DISF	exog	Discrepancy for f, B$.
DISG	exog	Discrepancy for g, B$.
DISH	exog	Discrepancy for h, B$.
DISR	exog	Discrepancy for r, B$.
DISS	exog	Discrepancy for s, B$.
DRS	exog	Dividends received by s, B$.
E	85	Total employment, civilian and military, millions.
EX	exog	Exports, B96$.
EXPG	106	Total expenditures, g, B$.
EXPS	113	Total expenditures, s, B$.
FA	exog	Farm gross product, B96$.
FIROW	exog	Payments of factor income to the rest of the world, B$.
FIROWD	exog	FIROW price deflator.
FIUS	exog	Receipts of factor income from the rest of the world, B$.
FIUSD	exog	FIUS price deflator.
G1	exog	Reserve requirement ratio.
GDP	82	Gross Domestic Product, B$.
GDPD	84	GDP price deflator.
GDPR	83	Gross Domestic Product, B96$.
GNP	129	Gross National Product, B$.
GNPD	131	GNP price deflator.

Variable	Eq.	Description
GNPR	130	Gross National Product, B96$.
HF	14	Average number of hours paid per job, f, hours per quarter.
HFF	100	Deviation of HF from its peak to peak interpolation.
HFS	exog	Peak to peak interpolation of HF.
HG	exog	Average number of hours paid per civilian job, g, hours per quarter.
HM	exog	Average number of hours paid per military job, g, hours per quarter.
HN	62	Average number of non overtime hours paid per job, f, hours per quarter.
HO	15	Average number of overtime hours paid per job, f, hours per quarter.
HS	exog	Average number of hours paid per job, s, hours per quarter.
IBTG	51	Indirect business taxes, g, B$.
IBTS	52	Indirect business taxes, s, B$.
IGZ	exog	Gross investment, g, B$.
IHB	exog	Residential investment, b, B96$.
IHF	exog	Residential investment, f, B96$.
IHH	4	Residential investment, h, B96$.
IHHA	exog	Peak to peak interpolation of IHH/POP.
IKB	exog	Nonresidential fixed investment, b, B96$.
IKF	92	Nonresidential fixed investment, f, B96$.
IKG	exog	Nonresidential fixed investment, g, B96$.
IKH	exog	Nonresidential fixed investment, h, B96$.
IM	27	Imports, B96$.
INS	exog	Insurance and pension reserves to h from g, B$.
INTF	19	Net interest payments, f, B$.
INTG	29	Net interest payments, g, B$.
INTOTH	exog	Net interest payments, other private business, B$.
INTROW	exog	Net interest payments, r, B$.
INTS	exog	Net interest payments, s, B$.
ISZ	exog	Gross investment, s, B$.
IVA	20	Inventory valuation adjustment, B$.
IVF	117	Inventory investment, f, B96$.
JF	13	Number of jobs, f, millions.
JG	exog	Number of civilian jobs, g, millions.
JHMIN	94	Number of worker hours required to produce Y, millions.
JJ	95	Ratio of the total number of worker hours paid for to the total population 16 and over.
JJP	exog	Potential value of JJ.
JM	exog	Number of military jobs, g, millions.
JS	exog	Number of jobs, s, millions.
KD	58	Stock of durable goods, B96$.
KH	59	Stock of housing, h, B96$.
KK	12	Stock of capital, f, B96$.
KKMIN	93	Amount of capital required to produce Y, B96$.
L1	5	Labor force of men 25-54, millions.
L2	6	Labor force of women 25-54, millions.
L3	7	Labor force of all others, 16+, millions.
LAM	exog	Amount of output capable of being produced per worker hour.
LM	8	Number of "moonlighters": difference between the total number of jobs (establishment data) and the total number of people employed (household survey data), millions.
M1	81	Money supply, end of quarter, B$.
MB	71	Net demand deposits and currency, b, B$.
MDIF	exog	Net increase in demand deposits and currency of banks in U.S. possessions plus change in demand deposits and currency of private nonbank financial institu-tions plus change in demand deposits and currency of federally sponsored credit agencies and mortgage pools minus mail float, U.S. government, B$.
MF	17	Demand deposits and currency, f, B$.
MG	exog	Demand deposits and currency, g, B$.
MH	9	Demand deposits and currency, h, B$.
MR	exog	Demand deposits and currency, r, B$.
MS	exog	Demand deposits and currency, s, B$.
MUH	exog	Amount of output capable of being produced per unit of capital.
PCD	37	Price deflator for CD.
PCGDPD	122	Percentage change in GDPD, annual rate, percentage points.
PCGDPR	123	Percentage change in GDPR, annual rate, percentage points.
PCM1	124	Percentage change in M1, annual rate, percentage points.
PCN	36	Price deflator for CN.
PCS	35	Price deflator for CS.
PD	33	Price deflator for X-EX+IM (domestic sales).
PEX	32	Price deflator for EX.
PF	10	Price deflator for X-FA.
PFA	exog	Price deflator for FA.
PG	40	Price deflator for COG.

Variable	Eq.	Description
PH	34	Price deflator for CS + CN + CD + IHH inclusive of indirect business taxes.
PI EB	exog	Before tax profits, b, B96$.
PI EF	67	Before tax profits, f, B$.
PI H	38	Price deflator for residential investment.
PI K	39	Price deflator for nonresidential fixed investment.
PI M	exog	Price deflator for IM.
PI V	42	Price deflator for inventory investment, adjusted.
POP	120	Noninstitutional population 16+, millions.
POP 1	exog	Noninstitutional population of men 25-54, millions.
POP 2	exog	Noninstitutional population of women 25-54, millions.
POP 3	exog	Noninstitutional population of all others, 16+, millions.
PROD	118	Output per paid for worker hour (“productivity”).
PS	41	Price deflator for COS.
PSI 1	exog	Ratio of PEX to PX.
PSI 2	exog	Ratio of PCS to (1 + D3G + D3S)PD.
PSI 3	exog	Ratio of PCN to (1 + D3G + D3S)PD.
PSI 4	exog	Ratio of PCD to (1 + D3G + D3S)PD.
PSI 5	exog	Ratio of PIH to PD.
PSI 6	exog	Ratio of PIK to PD.
PSI 7	exog	Ratio of PG to PD.
PSI 8	exog	Ratio of PS to PD.
PSI 9	exog	Ratio of PIV to PD.
PSI 10	exog	Ratio of WG to WF.
PSI 11	exog	Ratio of WM to WF.
PSI 12	exog	Ratio of WS to WF.
PSI 13	exog	Ratio of gross product of g and s to total employee hours of g and s.
PU G	104	Purchases of goods and services, g, B$.
PU S	110	Purchases of goods and services, s, B$.
PX	31	Price deflator for X.
Q	exog	Gold and foreign exchange, g, B$.
RB	23	Bond rate, percentage points.
RD	exog	Discount rate, percentage points.
RECG	105	Total receipts, g, B$.
RECS	112	Total receipts, s, B$.
RM	24	Mortgage rate, percentage points.
RMA	128	After-tax mortgage rate, percentage points.
RN T	exog	Rental income, h, B$.
RS	30	Three-month Treasury bill rate, percentage points.
RSA	130	After-tax bill rate, percentage points.
SB	72	Saving, b, B$.
SF	69	Saving, f, B$.
SG	76	Saving, g, B$.
SGP	107	NIA surplus (+) or deficit (-), g, B$.
SH	65	Saving, h, B$.
SH RP I E	121	Ratio of after-tax profits to the wage bill net of employer social security taxes.
SI F G	54	Employer social insurance contributions, f to g, B$.
SI F S	exog	Employer social insurance contributions, f to s, B$.
SI G	103	Total employer and employee social insurance contributions to g, B$.
SI GG	exog	Employer social insurance contributions, g to g, B$.
SI H G	53	Employee social insurance contributions, h to g, B$.
SI H S	exog	Employee social insurance contributions, h to s, B$.
SI S	109	Total employer and employee social insurance contributions to s, B$.
SI SS	exog	Employer social insurance contributions, s to s, B$.
SR	74	Saving, r, B$.
SRZ	116	Saving rate, h.
SS	78	Saving, s, B$.
SSP	114	NIA surplus (+) or deficit (-), s, B$.
ST AT	exog	Statistical discrepancy, B$.
ST AT P	exog	Statistical discrepancy relating to the use of chain type price indices, B96$.
SU BG	exog	Subsidies less current surplus of government enterprises, g, B$.
SU BS	exog	Subsidies less current surplus of government enterprises, s, B$.
T	exog	1 in 1952:1, 2 in 1952:2, etc.
TAUG	exog	Progressivity tax parameter in personal income tax equation for g.
TAUS	exog	Progressivity tax parameter in personal income tax equation for s.
TBG	exog	Corporate profit taxes, b to g, B$.
TBS	exog	Corporate profit taxes, b to s, B$.
TCG	102	Corporate profit tax receipts, g, B$.
TCS	108	Corporate profit tax receipts, s, B$.
TFG	49	Corporate profit taxes, f to g, B$.
TFS	50	Corporate profit taxes, f to s, B$.

Variable	Eq.	Description
THG	47	Personal income taxes, h to g, B$.
THS	48	Personal income taxes, h to s, B$.
TPG	101	Personal income tax receipts, g, B$.
TRFH	exog	Transfer payments, f to h, B$.
TRFR	exog	Transfer payments, f to r, B$.
TRGH	exog	Transfer payments, g to h, B$.
TRGR	exog	Transfer payments, g to r, B$.
TRGS	exog	Transfer payments, g to s, B$.
TRHR	exog	Transfer payments, h to r, B$.
TRRSH	111	Total transfer payments, s to h, B$.
TRSH	exog	Transfer payments, s to h, excluding unemployment insurance benefits, B$.
U	86	Number of people unemployed, millions.
UB	28	Unemployment insurance benefits, B$.
UBR	128	Unborrowed reserves, B$.
UR	87	Civilian unemployment rate.
V	63	Stock of inventories, f, B96$.
WA	126	After-tax wage rate. (Includes supplements to wages and salaries except employer contributions for social insurance.)
WF	16	Average hourly earnings excluding overtime of workers in f. (Includes supple ments to wages and salaries except employer contributions for social insurance.)
WG	44	Average hourly earnings of civilian workers in g. (Includes supplements to wages and salaries including employer contributions for social insurance.)
WH	43	Average hourly earnings excluding overtime of all workers. (Includes supple ments to wages and salaries except employer contributions for social insurance.)
WLDF	exog	Wage accruals less disbursements, f, B$.
WLDG	exog	Wage accruals less disbursements, g, B$.
WLDS	exog	Wage accruals less disbursements, s, B$.
WM	45	Average hourly earnings of military workers. (Includes supplements to wages and salaries including employer contributions for social insurance.)
WR	119	Real wage rate of workers in f. (Includes supplements to wages and salaries except employer contributions for social insurance.)
WS	46	Average hourly earnings of workers in s. (Includes supplements to wages and salaries including employer contributions for social insurance.)
X	60	Total sales f, B96$.
XX	61	Total sales, f, B$.
Y	11	Production, f, B96$.
YD	115	Disposable income, h, B$.
YNL	99	After-tax nonlabor income, h, B$.
YS	98	Potential output of the firm sector.
YT	64	Taxable income, h, B$.

Table B.3: The Stochastic Equations of the US Model

Eq.	**LHS Variable**	**Explanatory Variables**
Household Sector		
1	log(CS/POP)	cnst, AG1, AG2, AG3, log(CS/POP)- 1, log[YD/(POP·PH)], RSA, log(AA/POP)-1 , T [Consumer expenditures: services]
2	log(CN/POP)	cnst, AG1, AG2, AG3, log(CN/POP)- 1, ? log(CN/POP)- 1, log(AA/POP)- 1, log[YD/(POP·PH)], RMA [Consumer expenditures: nondurables]
3	CD/POP	cnst, AG1, AG2, AG3, DELD(KD/POP)-1 - (CD/POP)- 1, (KD/POP)- 1 , YD/(POP·PH), RMA·CDA, (AA/POP)- 1 [Consumer expenditures: durables]
4	IHH/POP	cnst, DELH(KH/POP)- 1 - (IHH/POP)- 1, (KH/POP)- 1, (AA/POP)- 1, YD/(POP·PH), RMA- 1IHHA, RHO =2 [Residential investment–h]
5	log(L1/POP1)	cnst, log(L1/POP1)- 1, log(AA/POP)- 1, UR [Labor force–men 25-54]
6	log(L2/POP2)	cnst, log(L2/POP2)- 1, log(WA/PH), log(AA/POP)- 1 [Labor force–women 25-54]
7	log(L3/POP3)	cnst, log(L3/POP1)- 1), log(WA/PH), log(AA/POP)- 1, UR [Labor force–all others 16+]

Eq.	LHS Variable	Explanatory Variables
8	log(LM/POP)	cnst, log(LM/POP)- 1, log(WA/PH), UR [Number of moonlighters]
9	log[MH/(POP·PH)]	cnst, log[MH- 1/(POP-1PH)], log[YD/(POP·PH)], RSA, T, D981, RHO=4 [Demand deposits and currency–h]
Firm Sector		
10	log PF	log PF- 1, log[WF(1 +D5G)]-log LAM, cnst, log PIM, UR, T [Price deflator for X-FA]
11	log Y	cnst, log Y- 1, log X, log V-1 , D593, D594, D601, RHO=3 [Production–f]
12	log KK	log(KK/KKMIN)- 1, ? log KK- 1 , ? log Y, ? log Y- 1, ? log Y-2 , ? log Y- 3, ? log Y- 4, ? log Y- 5, RB- 2(1 - D2G-2 - D2S- 2)- 100(PD-2 /PD- 6)- 1), (CG-2 +CG- 3 +CG- 4)/(PX- 2YS-2 + PX- 3YS- 3 +PX- 4YS- 4) [Stock of capital–f]
13	log JF	cnst, log[JF/(JHMIN/HFS)]- 1, ? log JF- 1, ? log Y, D593 [Number of jobs–f]
14	log HF	cnst, log(HF/HFS)-1 , log[JF/(JHMIN/HFS)]- 1 , ? log Y [Average number of hours paid per job–f]
15	log HO	cnst, HFF, HFF- 1, RHO =1 [Average number of overtime hours paid per job–f]
16	log WF-log LAM	log WF-1 -log LAM- 1, log PF, cnst, T, log PF-1 [Average hourly earnings excluding overtime–f]
17	log(MF/PF)	cnst, T, log(MF- 1 /PF), log(X- FA), RS(1 - D2G- D2S)- 1, D981 [Demand deposits and currency–f]
18	log DF	log[(PIEF- TFG- TFS)/DF-1] [Dividends paid–f]
19	INTF/(- AF+40)	cnst, [INTF/(- AF+40)]- 1, .75(1/400)[.3RS+.7(1/8)(RB+RB-1 +RB- 2 +RB- 3 +RB- 4 +RB-5 +RB-6 +RB- 7)], RHO =1 [Interest payments–f]
20	IVA	(PX- PX- 1)V- 1, RHO =1 [Inventory valuation adjustment]
21	log CCF	log[(PIK·IKF)/CCF- 1], cnst, D621, D722, D723, D923, D924, D941, D942, D013, D014, RHO =1 [Capital consumption–f]
Financial Sector		
22	BO/BR	cnst, (BO/BR)- 1, RS, RD [Bank borrowing from the Fed]
23	RB- RS-2	cnst, RB-1 - RS- 2, RS- RS- 2, RS- 1 - RS- 2, RHO =1 [Bond rate]
24	RM- RS- 2	cnst, RM-1 - RS- 2, RS- RS- 2, RS- 1 - RS- 2 [Mortgage rate]
25	CG/(PX - 1 ·YS- 1)	cnst, ? RB, [? (PIEF- TFG- TFS+PX·PIEB- TBG- TBS)]/(PX - 1 ·YS- 1) [Capital gains or losses on the financial assets of h]
26	log CUR/(POP·PF)	cnst, log[CUR- 1/(POP- 1PF)], log[(X - FA)/POP], RSA, RHO = 1 [Currency held outside banks]
Import Equation		
27	log(IM/POP)	cnst, log(IM/POP)- 1, log[(CS+CN+CD+IHH+IKF+IHB+IHF+IKB+IKH)/POP], log(PF/PIM), D691, D692, D714, D721, RHO =2 [Imports]
Government Sectors		
28	log UB	cnst, log UB- 1 , log U, log WF, RHO =1 [Unemployment insurance benefits]

Eq.	LHS Variable	Explanatory Variables
29	[INTG/(- AG)]	cnst, [INTG/(- AG)]- 1, .75(1/400)[.3RS+.7(1/8)(RB+RB-1 +RB-2 +RB- 3 +RB- 4 +RB-5 +RB-6 +RB- 7) [Three-month Treasury bill rate]
30	RS	cnst, RS- 1, 100[(PD/PD-1)4 - 1], UR, ? UR, PCM1- 1, D794823 · PCM1- 1, ?RS- 1, ?RS- 2

Table B.4: The Identities of the US Model

Eq.	LHS Variable	Explanatory Variables
31	*PX=*	[*PF(X- FA)+PFA·FA*]/ *X* [Price deflator for X]
32	*PEX=*	*PSI*1 ·*PX* [Price deflator for EX]
33	*PD=*	*(PX·X- PEX·EX+PIM·IM)/(X- EX+IM)* [Price deflator for domestic sales]
34	*PH=*	*(PCS·CS+PCN·CN+PCD·CD+PIH·IHH+IBTG+IBTS)/(CS+CN+CD+IHH)* [Price deflator for (CS + CN + CD + IHH) inclusive of indirect business taxes]
35	*PCS=*	*PSI*2*(*1 +*D*3*G*+*D*3*S)PD* [Price deflator for CS]
36	*PCN=*	*PSI*3*(*1 +*D*3*G*+*D*3*S)PD* [Price deflator for CN]
37	*PCD=*	*PSI*4*(*1 +*D*3*G*+*D*3*S)PD* [Price deflator for CD]
38	*PIH=*	*PSI*5 · *PD* [Price deflator for residential investment]
39	*PIK=*	*PSI*6 · *PD* [Price deflator for nonresidential fixed investment]
40	*PG=*	*PSI*7 · *PD* [Price deflator for COG]
41	*PS=*	*PSI*8 · *PD* [Price deflator for COS]
42	*PIV=*	*PSI*9 · *PD* [Price deflator for inventory investment]
43	*WH=*	100[*(WF·JF(HN* +1.5*HO)+WG·JG·HG+WM·JM·HM+WS·JS·HS- SIGG- SISS)/(JF(HN* + 1.5*HO)+JG·HG+ JM·HM+JS·HS)*] [Average hourly earnings excluding overtime of all workers]
44	*WG=*	*PSI*10 · *WF* [Average hourly earnings of civilian workers–g]
45	*WM=*	*PSI*11 · *WF* [Average hourly earnings of military workers]
46	*WS=*	*PSI*12 · *WF* [Average hourly earnings of workers–s]
47	*THG=*	[*D*1*G+((TAUG·YT)/POP)*]*YT* [Personal income taxes–h to g]
48	*THS=*	[*D*1*S+((TAUS·YT)/POP)*]*YT* [Personal income taxes–h to s]
49	*TFG=*	*D*2*G(PIEF- TFS)* [Corporate profits taxes–f to g]
50	*TFS=*	*D*2*S·PIEF* [Corporate profits taxes–f to s]

Eq.	LHS Variable	Explanatory Variables
51	$IBTG =$	$[D3G/(1+D3G)](PCS \cdot CS + PCN \cdot CN + PCD \cdot CD - IBTS)$ [Indirect business taxes–g]
52	$IBTS =$	$[D3S/(1+D3S)](PCS \cdot CS + PCN \cdot CN + PCD \cdot CD - IBTG)$ [Indirect business taxes–s]
53	$SIHG =$	$D4G[WF \cdot JF(HN + 1.5HO)]$ [Employee social insurance contributions–h to g]
54	$SIFG =$	$D5G[WF \cdot JF(HN + 1.5HO)]$ [Employer social insurance contributions–f to g]
57	$BR =$	$-G1 \cdot MB$ [Total bank reserves]
58	$KD =$	$(1 - DELD)KD_{-1} + CD$ [Stock of durable goods]
59	$KH =$	$(1 - DELH)KH_{-1} + IHH$ [Stock of housing–h]
60	$X =$	$CS + CN + CD + IHH + IKF + EX - IM + COG + COS + IKH + IKB + IKG + IHF + IHB - PIEB - CCB$ [Total sales–f]
61	$XX =$	$PCS \cdot CS + PCN \cdot CN + PCD \cdot CD + PIH \cdot IHH + PIK \cdot IKF + PEX \cdot EX - PIM \cdot IM + PG \cdot COG + PS \cdot COS + PIK(IKH + IKB + IKG) + PIH(IHF + IHB) - PX(PIEB + CCB) - IBTG - IBTS$ [Total nominal sales–f]
62	$HN =$	$HF - HO$ [Average number of non overtime hours paid per job–f]
63	$V =$	$V_{-1} + Y - X$ [Stock of inventories–f]
64	$YT =$	$WF \cdot JF(HN + 1.5HO) + WG \cdot JG \cdot HG + WM \cdot JM \cdot HM + WS \cdot JS \cdot HS + DF + DB - DRS + INTF + INTG + INTS + INTOTH + INTROW + RNT + TRFH - SIGG - SISS$ [Taxable income–h]
65	$SH =$	$YT + CCH - PCS \cdot CS - PCN \cdot CN - PCD \cdot CD - PIH \cdot IHH - PIK \cdot IKH - TRHR - THG - SIHG + TRGH - THS - SIHS + TRSH + UB + INS - WLDF$ [Saving–h]
66	$0 =$	$SH - ?AH - ?MH + CG - DISH$ [Budget constraint–h; (determines AH)]
67	$PIEF =$	$XX + PIV(V - V_{-1}) - WF \cdot JF(HN + 1.5HO) - RNT - TRFH - TRFR - CCH + SUBG + SUBS - INTF - INTOTH - INTROW - CCF - IVA - STAT - SIFG - SIFS + FIUS - FIROW - CCG - CCS + WLDG + WLDS + DISBA$ [Before tax profits–f]
68	$CF =$	$X - WF \cdot JF(HN + 1.5HO) - RNT - TRFH - TRFR - CCH + SUBG + SUBS - INTF - INTOTH - INTROW - PIK \cdot IKF - PIH \cdot IHF - SIFG - SIFS + FIUS - FIROW - CCG - CCS + WLDF$ [Cash flow–f]
69	$SF =$	$CF - TFG - TFS - DF$ [Saving–f]
70	$0 =$	$SF - AF - MF - DISF - STAT - WLDF + WLDG + WLDS + DISBA$ [Budget constraint–f; (determines AF)]
71	$0 =$	$MB + MH + MF + MR + MG + MS - CUR$ [Demand deposit identity; (determines MB)]
72	$SB =$	$PX(PIEB + CCB) - PIK \cdot IKB - PIH \cdot IHB - DB - TBG - TBS$ [Saving–b]
73	$0 =$	$SB - AB - MB - (BR - BO) - DISB$ [Budget constraint–b; (determines AB)]
74	$SR =$	$PIM \cdot IM + TRHR + TRGR + TRFR - PEX \cdot EX + FIROW - FIUS$ [Saving–r]
75	$0 =$	$SR - AR - MR + Q - DISR$ [Budget constraint–r; (determines AR)]

Eq.	LHS Variable	Explanatory Variables
76	$SG =$	$THG + IBTG + TFG + TBG + SIHG + SIFG - PG \cdot COG - WG \cdot JG \cdot HG - WM \cdot JM \cdot HM - INTG - TRGR - TRGH - TRGS - SUBG - INS + SIGG - PIK \cdot IKG + CCG$
		[Saving–g]
77	$0 =$	$SG - AG - MG + CUR + (BR - BO) - Q - DISG$
		[Budget constraint–g; (determines AG unless AG is exogenous)]
78	$SS =$	$THS + IBTS + TFS + TBS + SIHS + SIFS + TRGS + DRS - PS \cdot COS - WS \cdot JS \cdot HS - INTS - SUBS - TRSH - UB + SISS + CCS$
		[Saving–s]
79	$0 =$	$SS - AS - MS - DISS$
		[Budget constraint–s; (determines AS)]
80	$0 =$	$AH + AF + AB + AG + AS + AR - CG + DISH + DISF + DISB + DISG + DISS + DISR + STAT + WLDF - WLDG - WLDS - DISBA$
		[Asset identity (redundant equation)]
81	$M1 =$	$M1_{-1} + MH + MF + MR + MS + MDIF$
		[Money supply]
82	$GDP =$	$XX + PIV(V - V_{-1}) + IBTG + IBTS + WG \cdot JG \cdot HG + WM \cdot JM \cdot HM + WS \cdot JS \cdot HS + WLDG + WLDS + PX(PIEB + CCB)$
		[Nominal GDP]
83	$GDPR =$	$Y + PIEB + CCB + PSI13(JG \cdot HG + JM \cdot HM + JS \cdot HS) + STATP$
		[Real GDP]
84	$GDPD =$	$GDP/GDPR$
		[GDP price deflator]
85	$E =$	$JF + JG + JM + JS - LM$
		[Total employment, civilian and military]
86	$U =$	$L1 + L2 + L3 - E$
		[Number of people unemployed]
87	$UR =$	$U/(L1 + L2 + L3 - JM)$
		[Civilian unemployment rate]
89	$AA =$	$(AH + MH)/PH + (PIH \cdot KH)/PH$
		[Total net wealth–h]
90	$D1GM =$	$D1G + (2TAUG \cdot YT)/POP$
		[Marginal personal income tax rate–g]
91	$D1SM =$	$D1S + (2TAUS \cdot YT)/POP$
		[Marginal personal income tax rate–s]
92	$IKF =$	$KK - (1 - DELK)KK_{-1}$
		[Nonresidential fixed investment–f]
93	$KKMIN =$	Y/MUH
		[Amount of capital required to produce Y]
94	$JHMIN =$	Y/LAM
		[Number of worker hours required to produce Y]
95	$JJ =$	$(JF \cdot HF + JG \cdot HG + JM \cdot HM + JS \cdot HS)/POP$
		[Ratio of the total number of worker hours paid for to the total population 16 and over]
98	$YS =$	$LAM(JJP \cdot POP - JG \cdot HG - JM \cdot HM - JS \cdot HS)$
		[Potential output of the firm sector]
99	$YNL =$	$[1 - D1G - D1S - (TAUG + TAUS)(YT/POP)](RNT + DF + DB - DRS + INTF + INTG + INTS + INTOTH + INTROW + TRFH) + TRGH + TRSH + UB$
		[After-tax nonlabor income–h]
100	$HFF =$	$HF - HFS$
		[Deviation of HF from its peak to peak interpolation]
101	$TPG =$	THG
		[Personal income tax receipts–g]

Eq.	LHS Variable	Explanatory Variables
102	$TCG=$	$TFG+TBG$ [Corporate profit tax receipts–g]
103	$SIG=$	$SIHG+SIFG+SIGG$ [Total social insurance contributions to g]
104	$PUG=$	$PG\cdot COG+WG\cdot JG\cdot HG+WM\cdot JM\cdot HM+WLDG$ [Purchases of goods and services–g]
105	$RECG=$	$TPG+TCG+IBTG+SIG$ [Total receipts–g]
106	$EXPG=$	$PUG+TRGH+TRGR+TRGS+INTG+SUBG-WLDG-IGZ$ [Total expenditures–g]
107	$SGP=$	$RECG-EXPG$ [NIPA surplus or deficit–g]
108	$TCS=$	$TFS+TBS$ [Corporate profit tax receipts–s]
109	$SIS=$	$SIHS+SIFS+SISS$ [Total social insurance contributions to s]
110	$PUS=$	$PS\cdot COS+WS\cdot JS\cdot HS+WLDS$ [Purchases of goods and services–s]
111	$TRRSH=$	$TRSH+UB$ [Total transfer payments–s to h]
112	$RECS=$	$THS+TCS+IBTS+SIS+TRGS$ [Total receipts–s]
113	$EXPS=$	$PUS+TRRSH+INTS-DRS+SUBS-WLDS-ISZ$ [Total expenditures–s]
114	$SSP=$	$RECS-EXPS$ [NIPA surplus or deficit–s]
115	$YD=$	$WF\cdot JF(HN+1.5HO)+WG\cdot JG\cdot HG+WM\cdot JM\cdot HM+WS\cdot JS\cdot HS+RNT+DF+DB-DRS+INTF+INTG+INTS+INTOTH+INTROW+TRFH+TRGH+TRSH+UB-SIHG-SIHS-THG-THS-TRHR-SIGG-SISS$ [Disposable income–h]
116	$SRZ=$	$(YD-PCS\cdot CS-PCN\cdot CN-PCD\cdot CD)/YD$ [Saving rate–h]
117	$IVF=$	$V-V_{-1}$ [Inventory investment–f]
118	$PROD=$	$Y/(JF\cdot HF)$ [Output per paid for worker hour:“productivity”]
119	$WR=$	WF/PF [Real wage rate of workers in f]
120	POP	$=POP1+POP2+POP3$ [Noninstitutional population 16 and over]
121	$SHRPIE=$	$[(1-D2G-D2S)PIEF]/[WF\cdot JF(HN+1.5HO)]$ [Ratio of after-tax profits to the wage bill net of employer social security taxes]
122	$PCGDPR=$	$100[(GDPR/GDPR_{-1})^4-1]$ [Percentage change in GDPR]
123	$PCGDPD=$	$100[(GDPD/GDPD_{-1})^4-1]$ [Percentage change in GDPD]

Eq.	LHS Variable	Explanatory Variables
124	$PCM1 =$	$100[(M1/M1_{-1})^4 - 1]$
		[Percentage change in M1]
125	$UBR =$	$BR - BO$
		[Unborrowed reserves]
126	$WA =$	$100[(1 - D1GM - D1SM - D4G)[WF \cdot JF(HN + 1.5HO)] + (1 - D1GM - D1SM)(WG \cdot JG \cdot HG + WM \cdot JM \cdot HM + WS \cdot JS \cdot HS - SIGG - SISS)]/[JF(HN + 1.5HO) + JG \cdot HG + JM \cdot HM + JS \cdot HS]$
		[After-tax wage rate]
127	$RSA =$	$RS(1 - D1GM - D1SM)$
		[After-tax three-month Treasury bill rate]
128	$RMA =$	$RM(1 - D1GM - D1SM)$
		[After-tax mortgage rate]
129	$GNP =$	$GDP + FIUS - FIROW$
		[Nominal GNP]
130	$GNPR =$	$GDPR + FIUS/FIUSD - FIROW/FIROWD$
		[Real GNP]
131	$GNPD =$	$GNP/GNPR$
		[GNP price deflator]

Table B.5: The Raw NIPA Data

No.	Variable	Table	Line	Description
R1	GDP	1.1	1	Gross Domestic Product
R2	CDZ	1.1	3	Personal Consumption Expenditures, Durable Goods
R3	CNZ	1.1	4	Personal Consumption Expenditures, Nondurable Goods
R4	CSZ	1.1	5	Personal Consumption Expenditures, Services
R5	IKZ	1.1	8	Nonresidential Fixed Investment
R6	IHZ	1.1	11	Residential Fixed Investment
R7	IVZ	1.1	12	Change in Private Inventories
R8	EXZ	1.1	14	Exports
R9	IMZ	1.1	17	Imports
R10	PURGZ	1.1	21	Consumption Expenditures and Gross Investment, Federal Government
R11	PURSZ	1.1	24	Consumption Expenditures and Gross Investment, S&L
R12	GDPR	1.2	1	Real Gross Domestic Product
R13	CD	1.2	3	Real Personal Consumption Expenditures, Durable Goods
R14	CN	1.2	4	Real Personal Consumption Expenditures, Nondurable Goods
R15	CS	1.2	5	Real Personal Consumption Expenditures, Services
R16	IK	1.2	8	Real Nonresidential Fixed Investment
R17	IH	1.2	11	Real Residential Fixed Investment
R18	IV	1.2	12	Real Change in Private Inventories
R19	EX	1.2	14	Real Exports
R20	IM	1.2	17	Real Imports
R21	PURG	1.2	21	Real Federal Government Purchases
R22	PURS	1.2	24	Real State and Local Government Purchases
R23	FAZ	1.7	6	Farm Gross Domestic Product
R24	PROGZ	1.7	11	Federal Government Gross Domestic Product
R25	PROSZ	1.7	12	State and Local Government Domestic Gross Product
R26	FA	1.8	6	Real Farm Gross Domestic Product
R27	PROG	1.8	11	Real Federal Government Gross Domestic Product
R28	PROS	1.8	12	Real State and Local Government Gross Domestic Product

No.	Variable	Table	Line	Description
R29	FIUS	1.9	2	Receipts of Factor Income from the Rest of the World
R30	FIROW	1.9	3	Payments of Factor Income to the Rest of the World
R31	CCT	1.9	6	Private Consumption of Fixed Capital
R32	TRF	1.9	14	Business Transfer Payments
R33	STAT	1.9	15	Statistical Discrepancy
R34	WLDF	1.9	21	Wage Accruals less Disbursements
R35	DPER	1.9	23	Personal Dividend Income
R36	TRFH	1.9	25	Business Transfer Payments to Persons
R37	FIUSR	1.10	2	Real Receipts of Factor Income from the Rest of the World
R38	FIROWR	1.10	3	Real Payments of Factor Income to the Rest of the World
R39	COMPT	1.14	2	Compensation of Employees
R40	SIT	1.14	7	Employer Contributions for Social Insurance
R41	DC	1.14	25	Dividends
R42	PIECB	1.16	10	Profits Before Tax, Corporate Business
R43	DCB	1.16	13	Dividends, Corporate Business
R44	IVA	1.16	15	Inventory Valuation Adjustment, Corporate Business
R45	CCADCB	1.16	16	Capital Consumption Adjustment, Corporate Business
R46	INTF1	1.16	17	Net Interest, Corporate Business
R47	PIECBN	1.16	28	Profits Before Tax, Nonfinancial Corporate Business
R48	TCBN	1.16	29	Profits Tax Liability, Nonfinancial Corporate Business
R49	DCBN	1.16	31	Dividends, Nonfinancial Corporate Business
R50	CCADCBN	1.16	34	Capital Consumption Adjustment, Nonfinancial Corporate Business
R51	PRI	2.1	10	Proprietors' Income with Inventory Valuation and Capital Consumption Adjustments
R52	RNT	2.1	13	Rental Income of Persons with Capital Consumption Adjustment
R53	PII	2.1	15	Personal Interest Income
R54	UB	2.1	18	Government Unemployment Insurance Benefits
R55	IPP	2.1	28	Interest Paid by Persons
R56	TRHR	2.1	29	Personal Transfer Payments to Rest of the World (net)
R57	TPG	3.2	2	Personal Tax and Nontax Receipts, Federal Government (see below for Adjustments)
R58	TCG	3.2	5	Corporate Profits Tax Accruals, Federal Government
R59	IBTG	3.2	8	Indirect Business Tax and Nontax Accruals, Federal Government
R60	SIG	3.2	12	Contributions for Social Insurance, Federal Government
R61	CONGZ	3.2	14	Consumption Expenditures, Federal Government
R62	TRGH	3.2	16	Transfer Payments (net) to Persons, Federal Government (see below for Adjustments)
R63	TRGR	3.2	17	Transfer Payments (net) to Rest of the World, Federal Government
R64	TRGS	3.2	18	Grants in Aid to State and Local Governments, Federal Government
R65	INTG	3.2	19	Net Interest Paid, Federal Government
R66	SUBG	3.2	24	Subsidies less Current Surplus of Government Enterprises, Federal Government
R67	WLDG	3.2	27	Wage Accruals less Disbursements, Federal Government
R68	TPS	3.3	2	Personal Tax and Nontax Receipts, State and Local Government (S&L)
R69	TCS	3.3	6	Corporate Profits Tax Accruals, S&L
R70	IBTS	3.3	7	Indirect Business Tax and Nontax Accruals, S&L
R71	SIS	3.3	11	Contributions for Social Insurance, S&L
R72	CONSZ	3.3	14	Consumption Expenditures, S&L
R73	TRRSH	3.3	15	Transfer Payments to Persons, S&L
R74	INTS	3.3	16	Net Interest Paid, S&L
R75	SUBS	3.3	20	Subsidies Less Current Surplus of Government Enterprises, S&L

No.	Variable	Table	Line	Description
R76	WLDS	3.3	23	Wage Accruals less Disbursements, S&L
R77	COMPMIL	3.7b	8	Compensation of Employees, Military, Federal Government
R78	SIHGA	3.14	3	Personal Contributions for Social Insurance to the Federal Government, annual data only
R79	SIQGA	3.14	5	Government Employer Contributions for Social Insurance to the Federal Government, annual data only
R80	SIFGA	3.14	6	Other Employer Contributions for Social Insurance to the Federal Government, annual data only
R81	SIHSA	3.14	14	Personal Contributions for Social Insurance to the S&L Governments, annual data only
R82	SIQSA	3.14	16	Government Employer Contributions for Social Insurance to the S&L Governments, annual data only
R83	SIFSA	3.14	17	Other Employer Contributions for Social Insurance to the S&L Governments, annual data only
R84	IVFAZ	5.10	2	Change in Farm Private Inventories
R85	IVFA	5.11	2	Real Change in Farm Private Inventories
R86	INTPRIA	8.20	61	Net Interest, Sole Proprietorships and Partnerships, annual data only
R87	INTROWA	8.20	63	Net Interest, Rest of the World, annual data only

Table B.6: The Raw Flow of Funds Data

No.	Variable	Code	Description
R88	CDDCF	103020000	Change in Demand Deposits and Currency, F1
R89	NFIF	105000005	Net Financial Investment, F1
R90	IHFZ	105012003	Residential Construction, F1
R91	ACR	105030003	Access Rights from Federal Government
R92	PIEF	106060005	Profits before Tax, F1
R93	CCNF	106300015	Depreciation Charges, NIPA, F1
R94	DISF1	107005005	Discrepancy, F1
R95	CDDCNN	113020003	Change in Demand Deposits and Currency, NN
R96	NFINN	115000005	Net Financial Investment, NN
R97	IHNN	115012003	Residential Construction, NN
R98	CCNN	116300005	Consumption of Fixed Capital, NN. Also, Current Surplus = Gross Saving, NN
R99	CDDCFA	133020003	Change in Demand Deposits and Currency, FA
R100	NFIFA	135000005	Net Financial Investment, FA
R101	CCFAT	136300005	Consumption of Fixed Capital, FA
R102	PIEFA	136060005	Corporate Profits, FA
R103	CCADFA	136310103	Capital Consumption Adjustment, FA
R104	CDDCH1	153020005	Change in Checkable Deposits and Currency, H
R105	MVCE,	154090005	Total Financial Assets of Households.
R106	CCE		MVCE is the market value of the assets. CCE is the change in assets excluding capital gains and losses
R107	NFIH1	155000005	Net Financial Investment, H
R108	CCHFF	156300005	Total Consumption of Fixed Capital, H
R109	CCCD	156300103	Consumption of Fixed Capital, Consumer Durables, H
R110	DISH1	157005005	Discrepancy, H
R111	IKH1	165013005	Nonresidential Fixed Investment, Nonprofit Institutions
R112	NFIS	215000005	Net Financial Investment, S
R113	CCS	206300003	Consumption if Fixed Capital, S
R114	DISS1	217005005	Discrepancy, S
R115	CDDCS	213020005	Change in Demand Deposits and Currency, S
R116	CGLDR	263011005	Change in Gold and SDR's, R

R117	CDDCR	263020005	Change in U.S. Demand Deposits, R
R118	CFXUS	263111005	Change in U.S. Official Foreign Exchange and Net IMF Position-
R119	NFIR	265000005	Net Financial Investment, R
R120	PIEF2	266060005	Corporate Profits of Foreign Subsidiaries, F1
R121	DISR1	267005005	Discrepancy, R
R122	CGLDFXUS	313011005	Change in Gold, SDR's, and Foreign Exchange, US
R123	CDDCUS	313020005	Change in Demand Deposits and Currency, US
R124	INS	313154015	Insurance and Pension Reserves, US
R125	NFIUS	315000005	Net Financial Investment, US
R126	CCG	316300003	Consumption of Fixed Capital, US
R127	DISUS	317005005	Discrepancy, US
R128	CDDCCA	403020003	Change in Demand Deposits and Currency, CA
R129	NIACA	404090005	Net Increase in Financial Assets, CA
R130	NILCA	404190005	Net Increase in Liabilities, CA
R131	IKCAZ	405013005	Fixed Nonresidential Investment, CA
R132	GSCA	406000105	Gross Saving, CA
R133	DISCA	407005005	Discrepancy, CA
R134	NIDDLB2=		Net Increase in Liabilities in the form of Checkable Deposits, B2
R135		443127005	NIDDLZ1
R136		+473127003	NIDDLZ2
R137	CBRB2	443013053	Change in Reserves at Federal Reserve, B2
R138	IHBZ	645012205	Residential Construction, Multi Family Units, Reits
R139	CDDCB2=		Change in Demand Deposits and Currency, B2
R140		793020005- NIDDAB1 -CDDCCA	CDDCFS
R141	NIAB2=		Net Increase in Financial Assets, B2
R142		444090005	NIAZ1
R143		+474090005	NIAZ2
R144		+604090005	NIAZ3
R145		+544090005	NIAZ4
R146		+514090005	NIAZ5
R147		+574090005	NIAZ6
R148		+224090005	NIAZ7
R149		+634000005	NIAZ8
R150		+654090005	NIAZ9
R151		+554090005	NIAZ10
R152		+674190005	NIAZ11
R153		+614090005	NIAZ12
R154		+623065003	NIAZ13
R155		+644090005	NIAZ14
R156		+664090005	NIAZ15
R157		+504090005	NIAZ16
R158	NILB2=		Net Increase in Liabilities, B2
R159		444190005	NILZ1
R160		+474190005	NILZ2
R161		+604090005	NILZ3
R162		+544190005	NILZ4
R163		+514190005	NILZ5
R164		+573150005	NILZ6
R165		+223150005	NILZ7

R166		+634000005	NILZ8
R167		+653164005	NILZ9
R168		+554090005	NILZ10
R169		+674190005	NILZ11
R170		+614190005	NILZ12
R171		+624190005	NILZ13
R172		+644190005	NILZ14
R173		+664190005	NILZ15
R174		+504190005	NILZ16
R175	IKB2Z=		Nonresidential Fixed Investment, B2
R176		795013005 -IKB1Z -IKCAZ -IKMAZ	IKFCZ
R177	DISB2=		Discrepancy, B2
R178		447005005	DISZ1
R179		+477005005	DISZ2
R180		+607005005	DISZ3
R181		+547005005	DISZ4
R182		+517005005	DISZ5
R183		+657005005	DISZ9
R184		+677005005	DISZ11
R185		+617005005	DISZ12
R186		+647005005	DISZ14
R187		+667005005	DISZ15
R188	GSB2=		Gross Saving, B2
R190	+476000105	GSZ2	GSZ2
R191	+546000105	GSZ4	GSZ4
R192	+516000105	GSZ5	GSZ5
R193	+576330063	GSZ6	GSZ6
R194	+226330063	GSZ7	GSZ7
R195	+656006003	GSZ9	GSZ9
R196	+676330023	GSZ11	GSZ11
R197	+616000105	GSZ12	GSZ12
R198	+646000105	GSZ14	GSZ14
R199	+666000105	GSZ15	GSZ15
R200	CGLDFXMA	713011005	Change in Gold and Foreign Exchange, MA
R201	CFRLMA	713068003	Change in Federal Reserve Loans to Domestic Banks, MA
R202	NILBRMA	713113000	Change in Member Bank Reserves, MA
R203	NIDDLRMA	713122605	Change in Liabilities in the form of Demand Deposits and Currency due to Foreign of the MA
R204	NIDDLGMA	713123105	Change in Liabilities in the form of Demand Deposits and Currency due to U.S. Government of the MA
R205	NILCMA	713125005	Change in Liabilities in the form of Currency Outside Banks of the MA
R206	NIAMA	714090005	Net Increase in Financial Assets, MA
R207	NILMA	714190005	Net Increase in Liabilities, MA
R208	IKMAZ	715013005	Fixed Nonresidential Investment, MA
R209	GSMA	716000105	Gross Savings, MA
R210	DISMA	717005005	Discrepancy, MA
R211	CVCBRB1	723020005	Change in Vault Cash and Member Bank Reserves, U.S. Chartered Commercial Banks
R212	NILVCMA	723025000	Change in Liabilities in the form of Vault Cash of Commercial Banks of the MA
R213	NIDDAB1	743020003	Net increase in Financial Assets in the form of Demand Deposits and

			Currency of Banks in U.S. Possessions
R214	CBRB1A	753013003	Change in Reserves at Federal Reserve, Foreign Banking Offices in U.S.
R215	NIDDLB1	763120005	Net Increase in Liabilities in the form of Checkable Deposits, B1
R216	NIAB1	764090005	Net Increase in Financial Assets, B1
R217	NILB1	764190005	Net Increase in Liabilities, B1
R218	IKB1Z	765013005	Nonresidential Fixed Investment, B1
R219	GSB1	766000105	Gross Saving, B1
R220	DISB1	767005005	Discrepancy, B1
R221	MAILFLT1	903023105	Mail Float, U.S. Government
R222	MAILFLT2	903029205	Mail Float, Private Domestic Nonfinancial
R223	CTRH	155400263	Net Capital Transfers, Immigrants' transfers received by pesons
R224	CTHG	315400153	Net Capital Transfers, Estate and gift taxes paid by persons, federal
R225	CTHS	205400153	Net Capital Transfers, Estate and gift taxes paid by persons, state and local
R226	CTGS	205400313	Net Capital Transfers, Federal investment grants to state and local governments
R227	CTGR	265400313	Net Capital Transfers, Capital transfers paid to the rest of the world, federal
R228	CTGF	105400313	Net Capital Transfers, Investment grans to business, federal

Table B.7: Data from other Sources, Used in the U.S. Model

R229	RS	Three-Month Treasury Bill Rate (secondary market), percentage points. [BOG. Quarterly average.]
R230	RM	Conventional Mortgage Rate, percentage points. [BOG. Quarterly average.]
R231	RB	Moody's Aaa Corporate Bond Rate, percentage points. [BOG. Quarterly average.]
R232	RD	Discount Window Borrowing Rate, percentage points. [BOG. Quarterly average.]
R233	CE	Civilian Employment, SA in millions. [BLS. Quarterly average. See the next page for adjustments.]
R234	U	Unemployment, SA in millions. [BLS. Quarterly average. See the next page for adjustments.]
R235	CL1	Civilian Labor Force of Males 25-54, SA in millions. [BLS. Quarterly average. See the next page for adjustments.]
R236	CL2	Civilian Labor Force of Females 25-54, SA in millions. [BLS. Quarterly average. See the next page for adjustments.]
R237	AF	Total Armed Forces, millions. [Computed from population data from the U.S. Census Bureau. Quarterly average.]
R238	AF1	Armed Forces of Males 25-54, millions. [Computed from population data from the U.S. Census Bureau. Quarterly average.]
R239	AF2	Armed Forces of Females 25-54, millions. [Computed from population data from the U.S. Census Bureau. Quarterly average.]
R240	CPOP	Total civilian noninstitutional population 16 and over, millions. [BLS. Quarterly average. See the next page for adjustments.]
R241	CPOP1	Civilian noninstitutional population of males 25-54, millions. [BLS. Quarterly average. See the next page for adjustments.]
R242	CPOP2	Civilian noninstitutional population of females 25-54, millions. [BLS. Quarterly average. See the next page for adjustments.]
R243	JF	Employment, Total Private Sector, All Persons, SA in millions. [BLS, unpublished, "Basic Industry Data for the Economy less General Government, All Persons."]
R244	HF	Average Weekly Hours, Total Private Sector, All Persons, SA. [BLS, unpublished, "Basic Industry Data for the Economy less General Government, All Per sons."]
R245	HO	Average Weekly Overtime Hours in Manufacturing, SA. [BLS. Quarterly average.]
R246	JQ	Total Government Employment, SA in millions. [BLS. Quarterly average.]
R247	JG	Federal Government Employment, SA in millions. [BLS. Quarterly average.]
R248	JHQ	Total Government Employee Hours, SA in millions of hours per quarter. [BLS, Table B10. Quarterly average.]

Table B.8: Adjustments to Raw Data

No.	**Variable**	**Description**
R249	SIHG=	[SIHGA/(SIHGA + SIHSA)](SIG + SIS -SIT)
		[Employee Contributions for Social Insurance, h to g.]
R250	SIHS=	SIG + SIS -SIT -SIHG
		[Employee Contributions for Social Insurance, h to s.]
R251	SIFG=	[SIFGA/(SIFGA + SIQGA)](SIG -SIHG)
		[Employer Contributions for Social Insurance, f to g.]
R252	SIGG=	SIG -SIHG -SIFG
		[Employer Contributions for Social Insurance, g to g.]
R253	SIFS=	[SIFSA/(SIFSA + SIQSA)](SIS -SIHS)
		[Employer Contributions for Social Insurance, f to s.]
R254	SISS=	SIS -SIHS -SIFS
		[Employer Contributions for Social Insurance, s to s.]
R255	TBG=	[TCG/(TCG + TCS)](TCG + TCS -TCBN)
		[Corporate Profit Tax Accruals, b to g.]
R256	TBS=	TCG + TCS -TCBN -TBG
		[Corporate Profit Tax Accruals, b to s.]
R257	INTPRI=	[PII/(PII annual)]INTPRIA
		[Net Interest Payments, Sole Proprietorships and Partnerships.]
R258	INTROW=	[PII/(PII annual)]INTROWA
		[Net Interest Payments of r.]
	TPG=	TPG from raw data -TAXADJ
	TRGH=	TRGH from raw data -TAXADJ [TAXADJ: 1968:3 = 1.525, 1968:4 = 1.775, 1969:1 = 2.675, 1969:2 = 1969:3 = 1.775, 1969:4 = 1.825, 1970:1 = 1.25, 1970:2 = 1.25, 1970:3 = 1975:2 = -7.8.]
R259	POP=	CPOP + AF
		[Total noninstitutional population 16 and over, millions.]
R260	POP1=	CPOP1 + AF1
		[Total noninstitutional population of males 25-54, millions.]
R261	POP2=	CPOP2 + AF2
		[Total noninstitutional population of females 25-54, millions.]

A p p e n d i x C :

DETAILS OF THE MULTIMODAL TRANSPORTATION NETWORK

Data Sources for the Intermodal network

the underlying network and terminal databases CFS network construction involved merging mode-specific transportation network databases into a single, integrated multimodal network that allows both single and intermodal traffic routing between any pair of zip codes within the United States. This was accomplished by constructing of a single, logical network that can support the identification of any combination or sequence of intermodal paths. The network is "logical" in the sense that a computer program can find a chain of links between all possible origins and destinations. All of these network links represent some reality, whether physical trafficways, or processes that the shipment passes through in sequence, and they all have a geographic location. The resulting "links" in the CFS composite network therefore range from sections of real highway pavement to broad ocean sea lanes, to transfer processes involving cranes, drayage, storage, and repackaging at locations within a large seaport area. Two separate digital intermodal networks were constructed for traffic routing in the 1997 CFS: a truck-rail-waterways (TRW) network, and a truck-air (TA) network. Only the construction and application of the former network is the subject of this present paper. It was built by combining, and where necessary modifying, early 1997 calendar year versions of the following digital databases (see Southworth, 1997 for attribute details; also Southworth et al., 1998 for data sources):

? The Oak Ridge National Laboratory (ORNL) National Highway Network and its extensions into the main highways of Canada and Mexico.

? The Federal Railroad Administration's (FRA) National Rail Network and its extension into the main rail lines of Canada and Mexico.

? The US Army Corps of Engineers National Waterways Network.

? The ORNL constructed Trans-Oceanic Network.

? The ORNL constructed National Intermodal Terminals Database.

? A database of 5-Digit Zip-Code area locations.

For shipment routing purposes each of these databases may be thought of as a brick in the CFS multimodal network building exercise, while the modeling and data handling techniques described in this paper provide the mortar that was used to integrate them into a coherent network data structure. The intermodal terminals database similarly represents a major database development effort in its own right. Middendorf (1998) describes this database and its construction, including a list of the many different data sources that were used to build it.

Rectifying the Disparate Data Sources

For traffic routing purposes any differences in scale in measuring mileage and physical characteristics of the individual transportation modes are not important. What is important is the ability to connect networks together at appropriate (terminal) transfer locations. Once the usefulness of geographic detail has been established for a particular multimodal network it may be computationally efficient to simplify one or more of the constituent networks. For this purpose, prior to computing the number of links, a certain amount of highway end-on link chaining across county and other administrative borders was carried out. Note also that all network access and egress links, which are used to put freight on and off the network, were built on the fly by a set of CFS routing algorithms, as needed for specific shipments. Network modifications for routing purposes To support traffic routing each of the major mode-specific networks needed some modification and enhancement prior to being merged into the multimodal CFS network. Besides the addition of a few specific links, notably rail spur lines and terminal access connectors not already in these databases at the time, some other structural modifications were needed.

The ORNL National Highway Network was built specifically for, and has been used continuously in traffic routing studies for over a decade (Southworth et al., 1986; Chin et al., 1989). However, the CFS distinguishes between private and for-hire trucking sub-modes and reports separate statistics for each. Therefore where both private and for-hire trucking was listed in a shipment's mode sequence, efforts were made to identify likely truck (typically, cargo consolidation) terminals as intermediate stops on a route. These within-the highway-mode terminals were simulated as additional network links in a manner similar to intermodal transfer terminals.

For traffic routing purposes the National Waterway Network was divided into three different but connected sub-networks, following US Army Corps of Engineers definitions. These are the inland and inter-coastal (largely barge traffic) sub-network, the Great Lakes sub- network, and a trans-oceanic or "deep sea" sub-network. These distinctions are important for waterborne commerce routing because each of these sub-networks uses different vessel types to handle freight, since large, more robust vessels needed to cross large bodies of open water are uneconomical as a method of inland, riverine transport. Hence it was important to capture both the locations and relative costs involved in transferring goods from one vessel type to another. This was done by adding inter-vessel transfer links to the logical CFS network, at locations where such cargo unloading and loading takes place. For purposes of imputing within the United States export shipment mileages, where the US port of exit was unreported in the CFS, the ORNL trans-global deep sea sub-network was merged with this US waterways network. This deep sea sub-network takes the form of a lattice- work of open water links supplemented by much longer, more direct links between selected high volume seaport corridors (Southworth et al., 1998). It was linked by manual GIS-based editing to the National Waterways Network principally by adding connector links outside US seaports.

Two important aspects of modeling rail traffic routing involve railroad company specific "trackage rights" and between company "interlining" practices. To accommodate these the 1997 version of the FRA Rail Network was also subjected to modification prior to its inclusion within the CFS network. First, the representation of the railroad system as a connected set of individual companies' sub-networks was needed for traffic routing purposes. This required that each railroad link have a list of the companies that can operate over it, railroads that are said to have trackage rights. The FRA network included all trackage rights over a decade-long period, but we needed lists for 1997 only. This was accomplished by adding transition dates to ownership and trackage rights attribute information on each link. These dates were calculated from a model of corporate ancestry and the results were used to populate the geographic database. To accurately model rail routing, it is also necessary to know where traffic was being exchanged between railroad companies. These locations are known as interlines. While the FRA network contained some data on these they were assigned for the most part only in an approximate fashion to the nearest metropolitan area. To obtain the desired level of geographic specificity it was necessary to assign these interlines to specific network locations, by defining them as a set of inter-railroad connector links joining the pair of railroads involved. This link-by-link attribute editing of the rail network was carried out within a commercial GIS.

Finally, both the CFS rail and highway networks were extended to include major Canadian and Mexican rail lines and highways, each tied to the US domestic transportation networks by the addition of transfer links at border crossings. The cost of delays at customs stations can be attached to these transfer links to simulate the relative costs of alternative routes when considering truck and rail export shipments.

Construction of the Logical Multimodal Network

The multimodal CFS network was created by merging the above, now traffic routable single mode networks. This was done by linking them through a series of intermodal truck-rail (TR), truck-water (TW) and water-rail transfer terminals. Fig. 1 illustrates this concept, for the case for a truck-rail-truck (TRT) shipment. Using a suitable "shortest path" route-finding algorithm, a route is generated by first of all accessing the highway sub-network, linking this via a TR terminal to the rail sub-network and returning to the highway network via a second intermodal terminal transfer. In practice, two separate versions of the (same) highway sub-network are invoked in this routing procedure. Each of the three sub-networks shown may be activated or suppressed by suitable, user driven program commands to handle specific shipments, using a common sub- network selection software. This is done by invoking only those parts of the multimodal network database that are necessary for a specific shipment's routing exercise.

The correct mode sequence for intermodal trips is ensured as follows. We can begin by thinking of all of the CFS network's links as being "switched off", and by processing each reported shipment in turn. A copy of the highway portion of the CFS intermodal network is switched on. For the shipment shown in Fig. 1 a set of highway sub-network access links are generated from the traffic's origin (zip code) by the method describe in Section 4 of this paper. This is done for the first copy of the highway sub-network only. Similarly a set of destination egress links are created and indexed only to a second copy of the (structurally identical) highway sub-network. To bring the intermediate rail portion of the route into the picture the rail sub-network is also switched on as is a suitable subset of the CFS network's intermodal truck-to-rail terminal transfer links. All other terminal transfer links, including all rail-to-truck transfers are at this time turned off prior to shipment routing (by assigning them an infinite impedance as a starting default). The remaining, direction-specific terminal transfers then ensure the correct TRT routing sequence reported in the shipper survey. Finally, in making such terminal transfers it was often necessary to also generate, at execution time, a set of local terminal access and egress links not present in any of the modal sub- networks, and notably where the use of trucks was involved. These are also illustrated in Fig. 1.

Efficient organization of the multimodal shipments to be routed made for rapid computer processing on a shipment by shipment basis. Time saving computational procedures were also developed to recognize and store previously computed shipment routes. 2 Once the impedance for a network link or complete origin to destination route has been computed it can be stored for re- use in subsequent routing exercises. How these modal and intermodal impedances and their resulting routes were selected is discussed in Section 4.

Identification of Intermodal Route Selection

Putting CFS shipments onto the CFS network for the purpose of estimating mode and commodity specific ton-miles and dollar-miles of freight activity required a method or methods for first of all generating sensible single and multi-modal routes, and where more than one route was likely to be used, a method for assigning percentages of shipment volumes to each of these candidate routes. For consistency with the 1993 CFS single route truck freight modeling was used to compute 1997 CFS shipment distances. Single path waterway routing was also the norm. However, where rail dominated a route's mileage (both rail only and rail-inclusive intermodal routing) the situation was more complicated. More than one rail carrier-specific route was often both plausible and likely, and therefore each route needed to be both generated and assigned a portion of the origin-to-destination volume. Rail shipment volumes were then spread across a limited number of highly likely rail routes using a logit assignment model calibrated roughly to the tonnages carried on the high volume traffic corridors reported in the Surface Transportation Board's annual railcar waybill sample (AAR, 1998).

A "good" route, for CFS purposes, is a route that reproduces the shipper reported mode sequence and can either be validated using other data sources, or in the absence of such sources can stand up to some common sense rules associated with the economics of freight movement. Re- course to the literature on multimodal freight routing practices, including the work of Friesz et al. (1986), Harker (1997) and Guelat et al. (1990), indicates a complex set of factors influencing actual routes taken, involving carrier as well as shipper decisions, and one that also varies by commodity type. However, empirical validation of a large number of such mode and commodity specific route selection models was beyond the resources of the study. Nor would such a thing be easy to accomplish given the current state of freight movement data across the nation as a whole, and notably so for movements involving trucks (see Southworth, 1997). To ensure the selection of sensible routes, therefore, link specific impedances were developed to represent the generalized cost of different en route activities, including the costs of:

- ? Local access to major traffic ways and terminals;.
- ? Within terminal transfer activities including loading and unloading between modes, vehicles, and railroad companies.
- ? Negotiation of border crossings.
- ? The line haul costs in different corridors.

In all cases one or more routes through the CFS network are identified by a shortest path routine. Path length is determined here on the basis of a set of modal impedances This process starts with a set of what we term "native link impedance functions", i.e., native to the mode in question. In the case of the highway network these native impedances are assigned based on a number of link attributes, notably distance and urban and rural functional class, with default link traversal speeds modified on the basis of traffic conditions, access controls, the presence of a toll or a truck route designation and whether the highway is divided or not. The native impedance for highways is therefore a surrogate travel time impedance. Route selection over the railroad network, in contrast, is determined by an evaluation of line importance called "main line class". Though primarily based on traffic volumes (e.g., "branch" lines carry less than five million gross tons/year and "A-main" lines more than 30 million), we subjectively modified these classes on the basis of operating conditions and the principal commodities carried. Our routing procedure also required the identification and assignment of an impedance to those "interline" points where railcars may be transferred between separate railroad companies, data that is now a part of the rail network database. Waterway routings in contrast were comparatively straight-forward for the most part, as only a single waterway route was typically available and competitive. However, where Great Lakes transport was an option the differences in impedances, as well as the costs of transferring cargo from or to shallow draft barges needed to be incorporated into the network, requiring additional, within-mode cargo transfer links.

Given these native link impedances the next step is to determine the relative costs of transport between the different modes. This depends in reality on a number of shipment characteristics - value and weight, the importance of service reliability, ease of facility access and cargo handling, among others. Fortunately the CFS problem is made much simpler because the modes used are already known to the analyst. The routing problem is then one of locating these likely transfer points between modes. By and large we presumed that if a less expensive mode was used at all it was used preferentially for as large a proportion of the trip as practicable, relegating more ex- pensive modes to an access role. 3 This lead us to factor native modal impedances to ensure that the lowest cost mode would be used predominately, other things being equal. First, native impedances on each mode were scaled so that one mile of travel on the best type of facilities of that mode would incur one impedance penalty unit. 4 These native impedances were then multiplied by the following relative modal impedance factors to produce a unified network with consistent intermodal impedances:

Highway	1/1.0
Railroad	1/3.5
Inland water	1/5.8
Great Lakes	1/6.6
Ocean	1/7.0

In this approach the truck mode acts as the "base" or highest impedance mode. For example, one would accept a path that increased rail mileage 3.5 miles in order to reduce the highway portion of the trip by one mile. It should be noted that these relative modal impedance factors are not intended to estimate relative freight transport costs per se, or even generalized costs. They are used simply to force realistic route selections from which sensible mileage estimates can then be drawn. The general effect of using these impedance factors was to place the vast majority of the mileages on the least expensive mode. If water was used it dominated the route miles. Otherwise rail dominated, with highway usually acting as the mode of terminal access and/or egress where a great deal of intermodal routing was concerned. Once a set of intermodal routes had been generated a number of additional checks were carried out. In particular, a specific intermodal, terminal inclusive route was considered to be unreasonable if one or more of the following criteria was met:

? the route circuity factor was too high.

? there was an unlikely split between the different modal mileages.

? there existed contradictory expert knowledge.

Unlikely splits between modal mileages occur when the routing algorithm selects paths with long mileages on a more expensive mode relative to a less expensive one. This latter can also occur when the algorithm selects mode-specific mileages by going through a transfer terminal that produces mileages that are much longer than a direct trip by a single mode would be. With a little computer programming it was possible to pick out these questionable routings from among very long data lists and investigate these cases in more detail, subsequently using a GIS package to display questionable routes.

Alternative TR Routing Models

Many of the dubious cases identified by the above route validation criteria involved TR intermodal moves. A majority of the intermodal shipments reported in the 1997 CFS involve these two modes. To address these issues two different TR routing models were developed. These models are termed respectively the "major terminals" model and "distributed terminals" model. In particular, a distinction was made between containerized and non-containerized (bulk and break-bulk) freight. As shown in Fig. 6, freight designated as containerized by 1997 CFS shippers was handled by the major terminals model, and specifically by allowing TR transfers to occur only at those terminals where containerized traffic was known to be handled. 5 Where non-containerized shipments were concerned the ORNL terminals database provided the first set of candidate intermodal transfer locations tried by the rail-inclusive routing algorithms. If the resulting circuity was found to be unacceptably high for a specific origin- destination shipment, or if the resulting allocation of highway-to-rail mileage was deemed too high to warrant expensive rail-based intermodal transfers, then the alternative "distributed terminals" model was applied. In such cases a "major terminals" routing alternative was considered suspect when either of the following conditions was violated:

? When the route circuity is more than 2.5 times the Great Circle Distance,

? When the highway proportion of the entire origin-to-destination route length is greater than 25%.

A GIS is a valuable tool here for examining suspect terminal-inclusive routes. Rejection of a route led to the use of the "distributed terminals" model. This model assumes that for certain types of TR intermodal movement there will be a team track or other rail transfer facility within a reasonable distance of the shipment origin or destination (depending on the TR, RT, or TRT mode sequence involved). Without knowing where all of these terminals are located the model posits a TR transfer facility at the single closest node on each rail company's sub-network, for all rail nodes within a 90 mile search radius of the truck end of the trip. Once located, a highway route between a zip code traffic generator and these "ad hoc" terminals is then constructed. If the result obtained from this distributed terminals model was deemed significantly better, in the sense of the route being noticeably less circuitous than that supplied by the major terminals model, it was accepted. As a practical matter, access links to all major terminals are constructed by the ORNL routing procedures at network generation time. Access links to ad hoc terminals under the distributed terminals model are constructed at model execution time.

Handling Export Shipments.

Routing export shipments within the 1997 CFS required data on the US seaport of exit as well as the domestic origin and foreign destination of the movement. Where US port of exit data was missing from otherwise useful shipment records a method for imputing the most likely port of exit was devised. This was done by adding deep sea impedances to within- US truck, rail and/or waterway impedances associated with each export shipment. The resulting US port-inclusive, relative origin-to-destination impedances were then used to estimate a set of travel impedance-discounted comparative port attraction factors, with the most attractive port(s) being assigned the export shipments (Southworth et al., 1998). In terms of ton-mileage and other distance calculations the non-US portions of these routes are not reported by the CFS, so that the principal value of the routes to the survey is to identify the US origin to US port of exit mileages involved.

Appendix D

BUILDING AN APPLIED MULTIREGION IO MODEL

The World of Applied Regional Economic Models

While the intellectual exercise of developing a set of regional economic data, building a theoretical framework that can be applied to that data, and estimating the parameters of the model is (to a very few) an interesting activity in its own right, it is certainly not where the strength of such a model lies. To make such a model something more than a strictly academic exercise, it is necessary to build a tool that can be used to estimate the real economic impact of real economic shock to real regional economies. The world of applied regional economics revolves around a relatively small suite of economic modeling tools that are designed to answer these sorts of questions, and in this chapter we will develop our model into one additional tool to add to the mix. To begin, it is worthwhile to spend some time exploring the various modeling techniques currently in use in the regional economics community. We will then evolve our trade flow calculations into a full-fledged economic modeling tool that can (it is hoped) substantively improve the applied regional economic modeling toolbox.

The "Back of the Envelope" Economic Models

The vast majority of regional economic impact analysis is generally conducted, for better or worse, using a set of very simple (and hence inexpensive) modeling techniques. These techniques might better be characterized as "rules of thumb" then as any sort of true quantitative, technical and theoretically grounded modeling methodology. We will briefly describe two of the most widely used "back of the envelope" techniques, export base model and multiplier methods. While these techniques are clearly quite primitive, echoes of the techniques can be found in more sophisticated models, including the one developed in this paper. An important, and indeed almost ubiquitous, measure of economic impact used in all regional economic modeling is the multiplier. An employment multiplier, for example, measures the total increase in employment in a region when there is an increase of one job in some specific industry. Similar multipliers are frequently quoted for output and wages in an industry. Typically, as one might expect, multipliers exceed one, reflecting the fact that a new employee will spend some of his or her increased income on products produced in the local area, thus creating additional local jobs which in turn stimulate more local production, more income, etc. An employment (or output, or wage) multiplier is the estimate of the total employment change after all of these rounds of spending take place.

Export Base Models

Perhaps the earliest model of regional economic growth is the export base model, described by Isard et al (1998). The modeling technique is quite primitive, but is also still quite popular. The export base model is predicated on the assumption that exports outside the region are the only source of economic growth in the region. The employment multiplier in the export base model is:

$$K_e \; ? \; \frac{E}{B} \tag{6.1}$$

where the region's employment multiplier K_e is calculated as the ratio of total regional employment E to regional base (export) employment. By multiplying the relevant multiplier by the expected change in export employment, one can make a simple prediction of the number of new jobs that will be created in the region. For example, an employment multiplier of 1.6 predicts that adding 100 "export jobs" to the regional economy will lead ultimately to an additional 60 "non-export jobs" in the regional economy. Also implicit in the export base model is the assumption that any and all "non-export jobs" exist only in support of the export employment.

Not surprisingly, this model is relatively easy to use and commercial models built on this paradigm cost little or nothing for purchase and training. The principal cost of an export models is collecting employment data and determining export and non-export employment. It is, however, an inflexible tool, as it only capturers the very gross changes in export employment in the region. It also provides absolutely no detail on economic effects in or across individual industries. Beyond problems associated with quantifying export employment, the export base model provides a very limited and unrealistic model of economic growth. Differences in multipliers across industries and other sources of economic growth are ignored entirely. Factor inputs, such as labor, are assumed to always be available at the same price, and business costs, consumer prices, and profits are implicitly assumed to remain constant regardless of the economic conditions in the regional economy (Davis 1990).

Keynesian Multipliers

Another simple method which is closely related to export base models is the Keynesian multiplier approach (Bendavid-Val 1991). Instead of focusing on the factors driving employment growth, this approach models the amount of money "leaking out" of an economy. Any money that does not leak out of an economy will recirculate in the region, generating additional spending, income, and employment. For example, assuming that consumers' marginal propensity to consume is 70 percent (assuming no other leakage), then every $1 increase in income will lead to $.70 in additional spending locally ($ .30 being saved). This $.70 will in turn lead to additional sales locally of $.49, and so on. The income multiplier under the Keynesian approach is given by:

$$K_i = \frac{1}{1 - C} \qquad (6.2)$$

where the income multiplier K_i (for this simple example) is driven simply by the marginal propensity to consume C. With $C = .8$, an exogenous $1 increase in income will lead to $5 of total income being generated in the local economy. For anything like an accurate Keynesian multiplier, one must generally take into account other leakages, such as imports from other regions and taxes paid to governments outside the region. The advantage of this approach over the export base model is that other sources of economic growth, such as private and government consumption and investment, can be taken into account. Keynesian multipliers are usually estimated by developing simple macroeconomic type models of the determinants of consumption, investment, imports, and government taxation (Davis 1990). As with export base models, this method is generally of low cost to regional development professionals; most costs are associated with collecting data and developing models for consumption, investment, and imports. While this method is relatively easy to use once multipliers are developed, it has relatively low flexibility in adapting to different public policy interventions. Multipliers can be calculated for county economies, but generally very little disaggregation by industry is possible.

Enter the Software: the Sophisticated Modeling Techniques

The very simple multiplier approaches outlined above originated long before the ubiquitous availability of desktop computers, and hence the ability to develop applied models with significantly more complex internal structures. While many of these methods are relatively easy to use, fully understanding how they work requires a significant investment of time, an extensive understanding of regional economics. Without such an investment of time, the ability to use the models effectively and interpret the results correctly may be seriously compromised. However, these models generally offer much more flexibility, and much more potential to get accurate answers, than do the "back of the envelope" approaches. These methods generally require use of at least moderately expensive computer hardware and have significant data requirements.

Input-Output models

Input-output (IO) models are essentially as extension of the export base models to a multi-industry framework. A regional IO model is traditionally a single year snapshot of the regional economy. IO models are generally strongest in that they outline in great detail the ways in which the various sectors of the region's economy are meshed together and are linked to a variety of potential sources of exogenous economic shocks: changes in household consumption patterns, changes in residential and nonresidential investment, regional and extraregional government purchases and changes in regional exports or imports (Hearn and Tanner 2005). The heart of IO analysis, as outlined in chapter 2, the make and use tables. A second absolutely key part of input-output analysis is a table of regional purchase coefficients that describe the specific production technology of local industries. A technical coefficient indicates the percent of inputs used to produce a particular good that comes from other local industries. For example, a technical coefficient of 0.3 for a "processed foods" commodity indicates that 30 percent of demand for the processed foods commodity originating in the region is satisfied by producers in the region. By tracing the effects of production in one industry on other local industries, across the full range of intermediate purchases originating from the initial shock, IO analysis provides a more realistic estimate of industry specific output, input, and employment. Obviously, one of the principal chalenges in IO analysis is gathering the data to construct transaction tables for regional economies. Two principal methods have been employed: detailed surveys of local industries and modification of national make and use tables. The survey method is hypothetically the most accurate, but it is very costly and contingent on the comprehensiveness of the survey (Jensen 1990). Several commercially available software packages are available that use various techniques to regionalize national IO tables to model regional economies, without resorting to survey techniques. Among the most prominent commercial models that work within this framework are Implan (produced by Minnesota Implan Group, Inc.) and RIMS II (produced by the US Bureau of Economic Analysis).

The principal strength of these IO models is the wealth of information on interindustry transactions that they provide; a typical computer model contains up to 500 industries. The data available within the US are sufficient to produce IO models specific to county areas though states and

MSAs (Metropolitan Statistical Areas) are a more typical unit of analysis. The availability of computer IO software packages have put more sophisticated analysis capability in the hands of local practitioners. However these models have been limited in several key ways. IO models allow for only a single year snapshot of the effects of exogenous shocks to regional economies, effectively not allowing for only a dynamic image of the impacts of exogenous shocks. Commercial IO models are also limited to single region analysis; they only identify impacts of exogenous shock to a region on the region itself. With ever increasing interest in analyzing impacts across regions, multiregion IO analysis has been identified as a key area of research in regional economics (Isard et al 1998). Finally IO models are relatively inflexible for estimating the economic impact of many public policy changes, simply because they do not take into account most of the supply side of regional markets. Factors affecting the price of inputs and locally produced products as well as the competitiveness of local industries are entirely exogenous to IO models.

Econometric models

Regional econometric models are very often "spin-offs" of national macroeconomic models. There are a huge number of different specifications of such models, but all are similar in certain respects. Econometric models typically begin from a set of simple accounting identities, such as "industry output is equal to consumption of the commodity plus government spending on the commodity plus investment spending on the commodity plus net exports (exports minus imports) from the region." Once a complete set of accounting identities is in place, a set of behavioral equations are constructed to explain the behaviors not defined exclusively by the accounting identities. For example, household consumption can be modeled as a function of household disposable income and household characteristics. Household income might be further decomposed into wage and salary income, capital income (dividends and rents), and transfer payments, and equations can be built to explain each of these.

This building-block approach can lead to elaborate models with hundreds of equations of regional economies. A fully developed model, such as NRIES II produced by the BEA (Lienesch and Kort 1992), will create a quite comprehensive picture of the economy. However, because of the wide scope of econometric models, there are very significant data requirements, and getting such comprehensive data at any fine level of regional granularity (eg, at the county level) is tremendously challenging. Currently, most of these models are built for academic research or forecasting purposes and require significant modification, and often significant simplification in order to analyze policy changes in regional economies. Because of the significant data and programming requirements, most econometric models provide only limited geographic (state level) and industry disaggregation (50 industries or fewer). However, econometric models do typically allow for dynamic adjustments paths in key markets by including lagged variables. For example, a jump in the demand for labor in a particular industry will not lead immediately to the market-clearing wage rate. Instead, these models are generally more realistic in attempting to mirror the more gradual adjustments of actual markets.

Integrated Models

Perceived inadequacies in these two principal regional modeling approaches - IO analysis and econometric models - has led to interest in developing integrated models combining the best of both techniques (Beaumont 1990). Input-output models provide rich detail on the interindustry relationships within an economy while disregarding the role of pricing dynamics entirely. At the same time, econometric models have attempted to model a more complete set of key market behaviors, but such models sacrifice a great deal of detail on the industrial structure in a region. Integrated models use IO tables as the basis of their industrial structure and build a superstructure of econometric equations for other key economic variables on top of this foundation (e.g. Smith 1989; Treyz 1993).

Integrated models have continued to progress in detail and structure and now generally represent the state of the art in traditional regional modeling. However, they are not without their critics concerning both their underlying structure (Beaumont 1990) and forecasting accuracy (Crihfield and Campbell 1991). About the REMI model, Reaume (1994) argues that the model's attention to detail and neoclassical theory is both its strength and its weakness: its strength because the model records for future generations an approach to modeling which for many years epitomizes applied economics at its best: its weakness, because he has apparently not as yet accepted that the immense informational requirements of that approach simply cannot be met, even in principle. A second critical weakness that has been identified in this most "advanced" of economic models is that the layer upon layer of new behavioral equations (and underlying behavioral assumptions) that has been slathered on the underlying IO framework has rendered the results perilously close to indeterminate.

Despite the criticism of integrated models, they still represent the most sophisticated and comprehensive method available for carrying out economic impact analysis to date. The most popular of the integrated models is the REMI model developed by Treyz (1993). As illustrated in Figure 1, the REMI model is divided into five blocks that correspond closely to the model elements listed in Table 2. The lines illustrate the linkages between the key components of this model, which is composed of literally hundreds of equations.

Expanding upon the input-output and econometric models, REMI covers most of the key components of a regional economy (Table 2). REMI has also been designed specifically for economic impact analysis of policy changes. Hundreds of variables have been built into the model to allow for a wide range of public policy interventions. The model produces detailed information on employment, population, income, sales, exports, and prices for 53 industrial sectors. The commercial REMI model is built with all the basic data for the region already built in, and REMI maintains this database (for a fee) on an annual basis. While entering policy interventions into the REMI model is relatively easy, operating the REMI model and understanding required inputs and interpreting output of the model requires extensive training. Given the near indeterminate nature of the REMI model structure, proper use of this model might be impossible, regardless of the level of training.

Taking the First Step to a New Generation of Regional Modeling Tools

The author feels that the available set of regional modeling tools described above relies on dated and/or ill conceived model structures; hence the primary purpose of the trade flow calculation process of chapter 5 has been to begin developing a better technique for analyzing the regional economic impact of various development initiatives and other exogenous shocks to regional economies within the United States. Effective planning for public- and private-sector projects and programs at the state and local levels clearly requires a systematic analysis of the economic impacts of the projects and programs on affected regions. In turn, systematic analysis of economic impacts must account for the interindustry relationships within regions and between regions, because these relationships largely determine how regional economies are likely to respond to project and program changes. Thus, regional input-output models, which account for interindustry relationships within regions, have been key tools for regional economic impact analysis. Implicit to any of these regional modeling tools is a set of trade flow assumptions, which serve to capture the movement of money between industries and regions. The trade flow calculations outlined in chapter 5 represent, the author feels, a significant step forward in modeling these input-output relationships with some rigor. The trade flows calculated in chapter 5 have been used to develop a simple economic impact assessment compute model, for the purpose of enlightening users as to the economic implications of various policy alternatives. This chapter outlines a few practical considerations that have been addressed in developing the software. In addition, the reader may wish to refer to appendices D and E for a set of sample economic impact studies that have been undertaken using the "first generation" of this multiyear, multiregion IO model.

Producing the Forecasting Tool

A few additional key steps were used in turning our set of trade flows into a working forecast and analysis tool for economic impact assessment. First and foremost, we must translate our historical data and calculated trade flows to generate an (admittedly primitive) economic forecast for the counties. The economic forecast was generated in a relatively simple manner. First, recall our procedure outlined in chapter 3 for generated a comprehensive set of IO tables from the make and use tables built by the US Bureau of Economic Analysis (BEA) and the US Bureau of Labor Statistics (BLS). Recall also that the BLS make and use tables include a speculative ten year forecast set of tables (currently for 2012), designed to capture the forecast impact of technological change; while we have outlined the procedure for building annual tables out to 2012 and beyond using this information, we have not yet used this data. Now is the time.

The second tool used in developing the forecast is a somewhat modified version of the Macroeconomic model developed by Ray Fair (2004). The Fair model of the United States economy is perfectly suited to our needs, in that it generates a complete, forecast set of National Income and Product Accounts and Flow of Funds Accounts for the United States economy. The model was left largely untouched, though adjustments to the basic model structure were made to facilitate an annual (as opposed to quarterly) macroeconomic forecast. Also, a more detailed set of Census population projections were introduced to the model, to generate a more realistic long-run forecast, and finally, the model was adjusted to run a 20 year (as opposed to a seven year) economic forecast. A description of the Fair model, and of our modification to it, may be found in Appendix B.

Once the NIPA data has been forecast, the forecast IO tables are RASed to match the forecast NIPA “final demand” components – which produces a comprehensive picture of the US economy that is consistent with the historical US totals and the historical US IO tables. A five year moving average of the regional industry output is used to forecast regional industry output through the forecast period, and this forecast is then scaled to hit the forecast US totals.

At this point, we make a key (and somewhat unrealistic) assumption that the trade flow proportions among regions shall remain unchanged throughout the forecast period, so, for example, if 10% of all forest products output of county $\tilde{r}$ are sold in county r in the trade flow calculations from chapter 5, the same will hold true throughout the forecast period. As such, the forecast regional output totals are RASed to hit the implied aggregate demand totals from the trade flow relationships. This procedure, as it turns out, leaves the regional forecasts almost completely unaffected; that is, the assumption of constant trade proportions does not significantly affect the integrity of the basic regional forecasts. Once this forecast is generated, we also generate an employment (by industry) forecast, based upon the BLS employment forecast for 2012 (consistent, by design, with their 2012 IO tables), and the relative productivity (wages) by industry for each region.

Once this is done, we have generated a complete set of regional data and trade relationships though (currently) 2024. The forecast itself is not the (primary) point. Rather, this is to be used as a tool to calculate the regional impact of exogenous shocks to regional economies. In the current incarnation of the model these shocks take the form of exogenous changes in output, or employment (and hence, indirectly, output), compensated by equal sized changes in the region's industry's international exports. The change in international exports is sufficient to maintain the shock as truly and absolutely exogenous – the exogenously introduced change in output becomes, in essence, a change in the amount exported internationally and, hence, "out of the model." This means that introduction of additional exogenous output will not in any way crowd out producers in other regions in the model, and an exogenous decrease in output will not result in an unexploited market that must be filled endogenously. These assumptions are by no means necessitated by the model structure, and, in fact, there are plans to provide for several other alternative assumptions. In addition, the software could be readily expanded to allow users to tweak any number of other variables in the model; this will be added as resources allow. Finally, the most exciting modifications – the introduction of dynamic computable general equilibrium responses, and of rational expectations, are outlined in Chapter 7.

While there are many additional modifications and extensions that may be added, the model as it stands is certainly a valuable contribution to the practice of regional economic impact analysis, in that the model represents:

- ? the best U.S. forecast of any regional economic model of the United States, with new U.S. data introduced every quarter.
- ? greater industry detail than any other regional modeling tool, with a full five digit NAICS code level of detail (709 industries).
- ? The only massively multiregional modeling tool with the ability to consistently and completely model interregional relationships among all counties in the United States (3110 regions).
- ? the only model that "knows" transportation infrastructure, with every transportation commodity entering into the estimation of transportation costs and elasticities of substitution explicitly.
- ? The only model with a consistent and theoretically sound technique for estimating trade flows of non-manufacturing commodities.

Needless to say, the development of the software application involved overcoming extensive technological hurdles, as well as interesting code optimization and interface design issues; the purpose of this paper, however, is to outline the economics of the model, rather than the programming aspects, so these issues will be left for another time.

That said, some readers might be interested to see what the model predicts in terms of the economic implications of several "real life" economic impact questions. To that end, appendices D and E contains several economic impact case studies conducted using the newly developed model (dubbed Regional Dynamics, or ReDyn outside the state of Georgia and GEMS – for the Georgia Economic Modeling System, within the state). In addition, each of these studies were tested against the leading commercial economic impact models REMI, Implan, and RIMS II, to guarantee the consistency and reasonableness of model responses, relative to these other modeling tools.

Appendix E

THE ECONOMIC IMPACT OF TOURSIM INTITATIVES FOR GREENWOOD, SOUTH CAROLINA

Introduction

Tom Tanner, of the Carl Vinson Institute of Government, was retained by The Partnership for Greater Greenwood County and Economic Alliance, to conduct a quantitative economic impact analysis of the implications of a proposed capital investment and tourism promotion intitative on Greenwood county. This analysis has covered the economic impact of a range of capital spending and ongoing tourism promotions spending options, as well as an analysis of a range of possible tourism spending scenarios; to fairly judge these initiatives, the negative economic implications of additional sales tax collections was also fully considered. The analysis includes the net economic implications of a full range of alternative scenarios (levels of revenue collection and levels of tourism attracted to the region), as well as the fiscal implications of these various scenarios. Finally, a general analysis was conducted to show the aggregate economic and fiscal impacts on Greenwood County of a typical level of capital investment in the county. This report summarizes our findings.

Assumptions and Data Used in the Analysis

In analyzing the impact of sales tax revenue and resultant spending on downtown capital improvement projects and tourism promotion, a total of six scenarios were analyzed. Data provided by Greenwood County estimated that sufficient revenue would be generated to support between $10 million and $14 million in capital improvement project, in addition to supporting between $200,000 and $400,000 of ongoing spending on tourism promotion. In light of this information, a set of high revenue and a set of low revenue impact scenarios were conducted. The high revenue impact scenarios assumed that sufficient revenue is generated to support $14 million in capital improvements and $400,000 in operations spending, and all low revenue impact scenarios assumed that sufficient revenue is generated to support a total of $10 million in capital improvements and $200,000 in operations spending.

Regardless of the revenue scenario, the assumption was that part of the capital expenditures would go toward total funding of the proposed Federal Building upgrades (a total of $7.5 million in construction spending and $250,000 in spending on furnishings). Further, it was assumed that this spending would result in the additional Federal Building revenue streams identified in their proposal to the county (a total of $157,800 per year in additional rent revenue, and $120,000 per year in additional gift shop revenue), and that all of this represents net new spending in the county. All additional capital spending was assumed to go to general nonresidential capital purchases, and all operations spending was assumed to follow the spending profile for general local government spending.

The revenue generation and capital and operations expenditures scenarios themselves are not particularly subject to speculation. However, the general capital improvement and operations spending is tailored specifically to attracting additional tourism (and hence additional tourism spending) to the community. A critical component of the analysis depends entirely on how successful these capital improvement and tourism promotion efforts actual are at attracting new tourism dollars to the region.

Unfortunately, no firm data was available on the amount of additional tourism revenue could be expected as a result of these capital and operating expenditures. In light of this, the analyst provided for three alternative tourism scenarios, based upon information available on the experience of the Newberry Opera House in Newberry, South Carolina. The capital investment program for the Newberry Opera House totaled just over $9.6 million, approximately equal to the amount of investment associated with the proposed capital improvements in Greenwood. This, and the proximity of the Opera House investment to Greenwood, suggests that these two capital improvement programs might be roughly comparable.

For each of the two revenue scenarios, three alternative tourism scenarios were considered. The "high tourism" scenario assumed that all general capital spending (that is, all spending not associated with the Federal Building) manages to attract tourism dollars at the same rate as was generated by the Opera House investment. The "moderate tourism" scenario assumes that all general capital spending manages to attract tourism dollars at half the rate as was generated by the Opera House investment. Finally, the "low tourism" scenario assumes all general capital spending manages to attract tourism dollars at only 10% of the rate that was generated by the Opera House investment. While these assumptions are admittedly loose, they are also quite conservative – assuming, in the most optimistic scenario, that tourism dollars cannot be generated any more efficiently than they were generated by the Newberry Opera House project, and the pessimistic scenario assumes very little tourism impact at all. These scenarios are also conservative in that they assume no quality of life or "amenity value" improvements to the region; that is, that tourism is the only nonmarket benefit to be found in the new spending.

Finally, the reader should be made to understand that the analysis includes the negative economic impact of the additional sales tax collections, so all reported impacts are the net of the positive impact of the additional spending and tourism AND the negative impact of the additional sales tax itself.

The Economic Impact Analysis Process

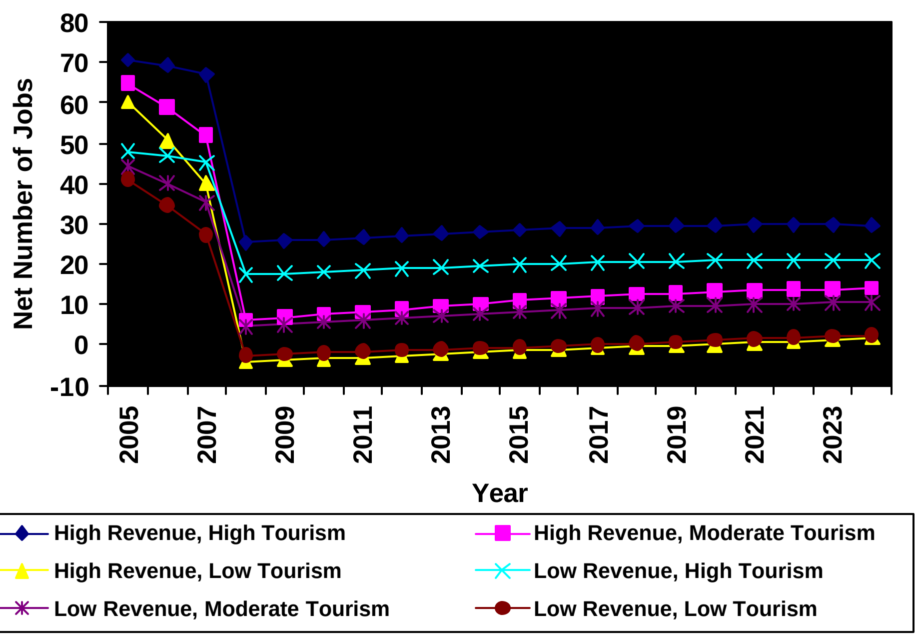
The economic impact of each of these six scenarios was conducted using the Regional Dynamics economic modeling tool, developed by Regional Dynamics, Inc. and the Carl Vinson Institute of Government. This economic model comprehensively estimates the flow and impact of resources among all industries and all counties in the United States, and can be used to quantify the overall impact of an exogenous shock to a regional economy, both over time and across regions. The processes used in the model are both comprehensive and complex; a more complete description of the model can be found in Appendix A.

Results

By introducing each of the six alternative scenarios outlined earlier into the model, we were able to come up with an array of potential impacts for the proposed revenue and expenditure streams, which will vary depending on both the level of revenue collected and on the amount of tourism generated as a result of the initiative. While the analysis examined the impacts in great detail, we will limit our discussion to a few key variables, namely employment impact, wage bill impact, output impact, local government revenue impact, local government expenditure impact, and net revenue impact. Each of these will be briefly outlined in this report.

Employment Impact

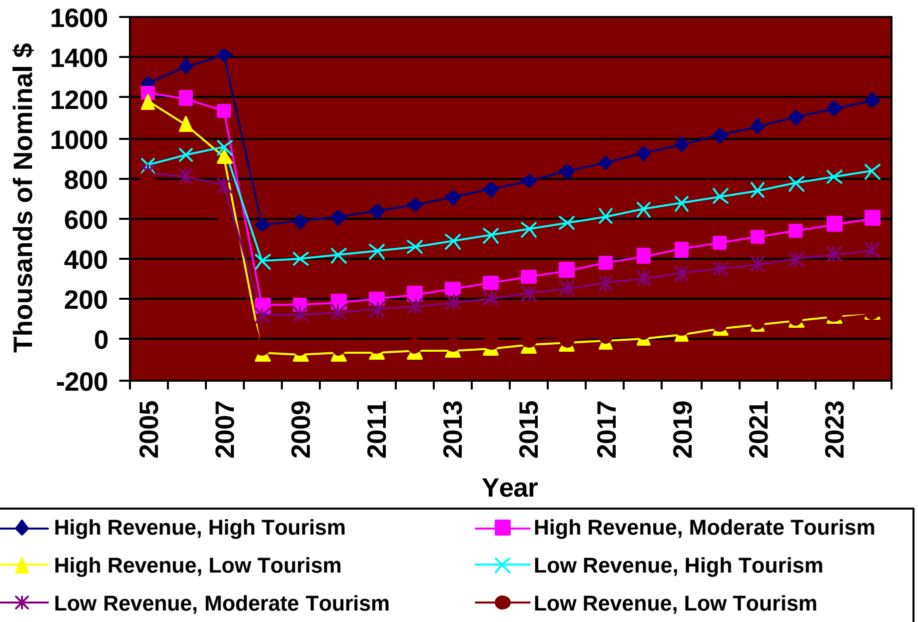
Figure 1: Employment Impact



Regardless of the amount of capital spending and tourism brought to the region under these scenarios, the employment impact is expected to be positive and significant throughout the three years of capital improvements, representing approximately 30 to 70 additional jobs in Greenwood County. From the end of the construction phase to the end of the forecast period, the employment impact is forecast to be much more modest, varying from 25-30 jobs in the most optimistic scenario to virtually no net employment gain in the "low tourism" scenarios. The employment impact is forecast to be very slightly negative in the worst case tourism scenarios, but the numbers are so small as to be essentially zero. Recall again that all forecasts include the slight negative impact of any additional sales tax revenue, and so represent the true net gain or loss in employment, and recall also that all assumptions underlying these scenarios were deliberately quite conservative.

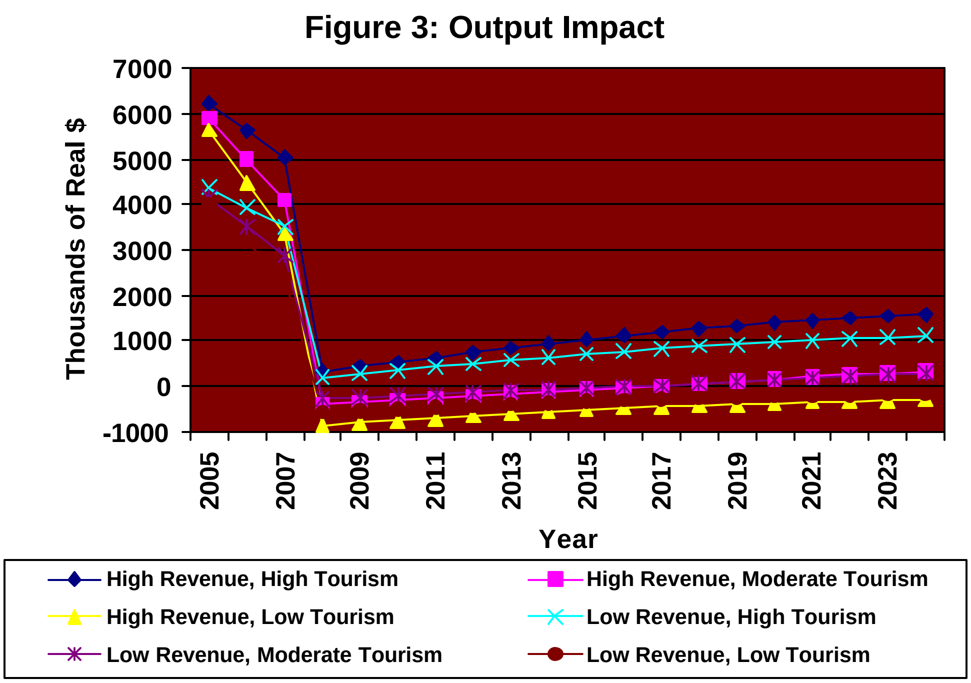
Wage Bill Impact

Figure 2: Wage Bill Impact



Not surprisingly, the impact of these investment spending and tourism measures are almost precisely the same impact on the total wage bill of the county as they did on total employment. Regardless of the level of capital spending and tourism brought to the region under these scenarios, the impact on total wages in the county is expected to be positive and significant throughout the three years of capital improvements, with an additional $600 thousand to $1.4 million in wages being paid per year in Greenwood County over the three year period. From the end of the construction phase to the end of the forecast period, the wage bill impact follows the modest employment forecast, with wages in 2008 (the first "post construction" year)varying from just under $600 thousand in the most optimistic scenario, to very slightly negative (virtually no impact) in the most pessimistic tourism scenarios. Over time, as wages rise with prices, the total wage bill impact in every scenario becomes positive. By 2024, the impact of the capital improvement and tourism initiatives is forecast to bring between $150,000 and $1.2 million in additional wages to the region per year.

Output Impact



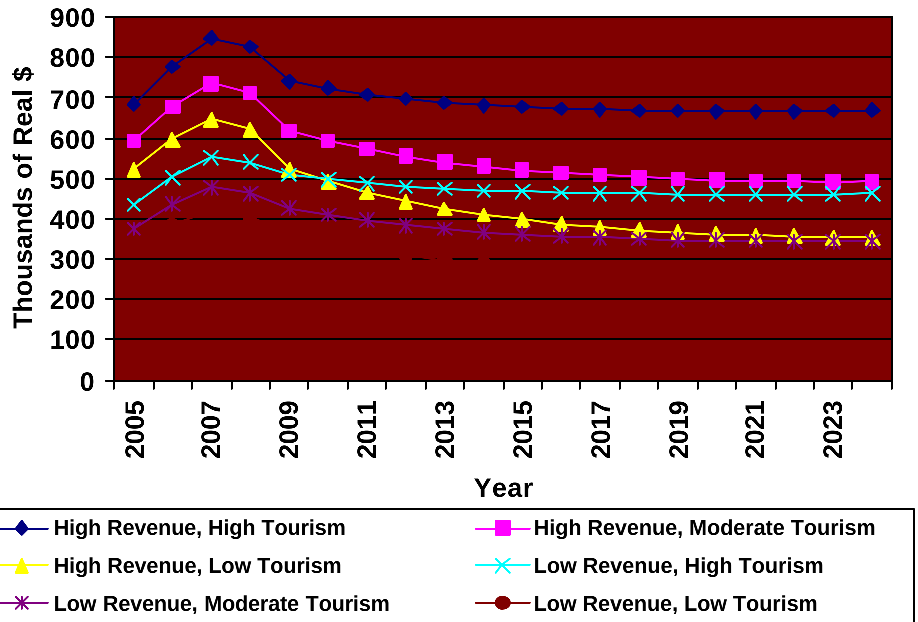
As with employment and wages, the impact of the construction phase (2005-2007) on output is expected to be positive and significant in every scenario analyzed. The impact over these three years in every one of the six scenarios is between $2.5 million and $6.5 million dollars per year. The impact at the close of the construction period once again varies depending upon the tourism scenario that is realized. Under the best case tourism scenario, output remains positive throughout the forecast period, averaging approximately $1 million dollars per year. Under the middle case scenario, output in

Greenwood county is expected not to change at all, and under the profoundly pessimistic scenario, output in the county is forecast to be slightly lower than it would have been otherwise.

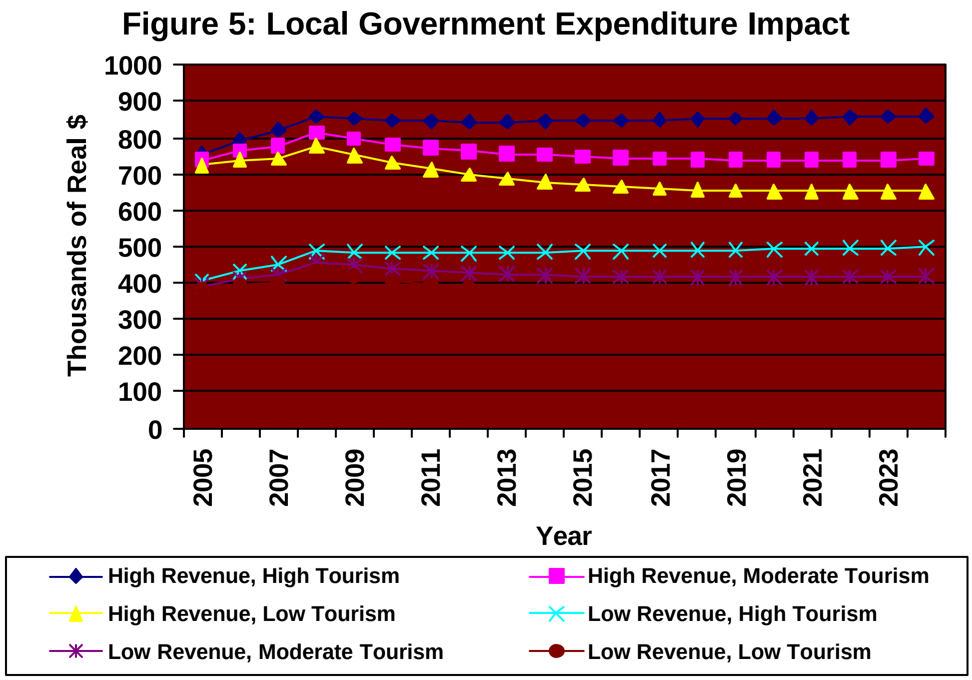
Local Government Fiscal Impact

The net fiscal impact of these capital expenditures and related tourism growth are expected to be absolutely minimal. The fiscal analysis calculates the expected revenue streams, based upon estimated historical local revenue collections and the forecast economic impact, as well as expected expenditures, based upon expected future economic growth (particularly population growth), and the estimated historical level of government service provision in the county. The net fiscal impact, naturally, is the total revenue impact minus the total expenditure impact

Figure 4: Local Government Revenue Impact



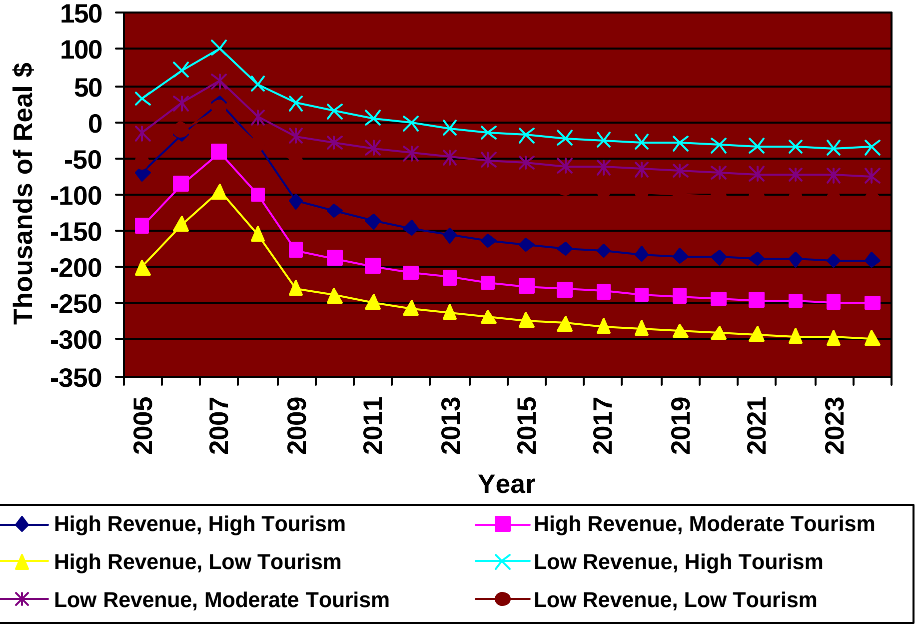
The total revenue impact of the capital spending and tourism is expected to be at its highest during the construction years, 2003-2005., and is expected to generate between $400 thousand and $850 thousand in the peak year, depending on the scenario. Revenue begins to level off after the construction phase, such that, by 2024, the local government is expected to be generating between $250 and $650 thousand per year in additional revenue, as a result of these actions.



As the new construction spending, and subsequent tourism dollars bring new employment opportunity in the region, they are also expected to bring more people, and more demand for government services. As a result, government expenditures (assuming the government maintains current service levels and cannot benefit from "economies of scale") are expected to increase by approximately $400 thousand to $800 thousand dollars per year, depending on the forecast assumptions regarding the level of capital spending and the tourism response.

The net fiscal impact (revenue minus expenditure) resulting from these forecasts depends once again on the scenario under consideration. Under the assumption of low revenue collection combined with a high tourism response is essentially revenue neutral (a slight surplus is generated through 2011, and very slight deficits are forecast for 2012-2024. Under the worst case forecasts, the net revenue impact is forecast to be negative, though modest, throughout the forecast period.

Figure 6: Local Government Net Revenue Impact



The Impact of Expected Capital Investment in Greenwood County.

One final scenario was conducted for this project, to analyze in very general terms the impact on Greenwood County of all expected investment spending in the county. Greenwood County officials were able to identify a total of $108.22 million worth of investment that has taken place or is expected to take place between 2004 and 2010 in the county – projects ranging from the library campaign, to upgrading arts facilities, to hospital expansion and private development initiatives. In light of this, the model was used to analyze what the impact of this level of investment (an average of $15.46 million per year) is on the Greenwood County economy. Figure 7-10 outline the impact of a stream of $15.46 million dollars of capital investment per year on Greenwood County.