TRADE AND SPATIAL ECONOMIC INTERDEPENDENCE:
U.S. INTERREGIONAL TRADE AND REGIONAL ECONOMIC STRUCTURE

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Geography
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2010

Urbana, Illinois

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ABSTRACT

This dissertation was motivated by the changing nature and structure of interregional trade within a country. Each region's economic structural changes and new spatial organization of production generated by the fragmented production process made possible by an open economy with significantly lower transportation costs have resulted in complex and changing patterns of interregional trade. For this reason, more attention has been directed to the relationship between trade and spatial economic interdependence across diverse regions. Such changes in the interregional or interstate trade pattern have raised several questions as follows: *where are the main sources of inputs and markets for each region and how have they changed over time?; to what extent is interregional trade beneficial to the regions?; and what, if any, related public policies might be considered to enhance the region's economic well being?*

This dissertation comprises three main essays to explore the U.S. interregional trade and regional economic structure in order to seek for the answers to the research questions presented above. The focus is three aspects: (1) the spatial pattern of the U.S. interstate commodity flows, (2) the role of interregional trade in the U.S. economy, and (3) spatial economic interdependence in the U.S. regional economy. The first analysis explores the spatial or geographical patterns of U.S. interstate commodity flows by employing two main exploratory spatial data analyses using U.S. CFS data. The analyses reveals trends that highlight the expanding interregional trading regions for each U.S. state between 1993 and 2007 even though there is significant spatial and temporal stability in the interstate commodity flow patterns. The second analysis focuses on investigating the role of interregional trade in regional economic growth. In order to assess the interregional trade coefficient change effects to the changes in the regional output level, a regional output decomposition method is introduced. The decomposition method is based on

the interregional input-output model, and separates the interregional input-output coefficients for the intermediate transaction into pure technical coefficient and interregional trade coefficients. This decomposition approach highlights the significant role of trade among regions in generating and distributing the regional output across the regions. The final analysis explores the spatial economic interdependence among regions within an interregional economic system. The hypothetical extraction methods are applied to reveal that there is a clear hierarchical spatial linkage among regions. This dissertation provides the basis for understanding the relationship between interregional trade and spatial economic interdependence within the entire U.S. regional economy. It presents the changing structure of interregional trade and detects the significance of interregional trade. More regional "spillover" effects through the interregional interaction could be expected over time and the increasing interregional or interstate trade will continue to enhance each region's complementarity as well change the nature of its competitiveness. There is a clear implication for the importance of transportation infrastructure investment in developing and promoting the growth and development of the entire regional economy. Future assessment of the regional economic impact of transportation infrastructure development would require the creation of an integrated model linking interregional input-output systems with a transportation network model. Given concerns about climate change and the environmental implications of future development, such a model would be able to explore the nature and extent of negative externalities associated with the growth of interregional trade as well as the implications for energy demands to move greater volumes of goods and services over longer distances

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Chapter 1

Introduction

1. Overview

Interregional trade has increased gradually as regions within a country or in the world have been rapidly integrated with each other into one open economy. According to new estimates of Commodity Flows Survey (CFS) by the Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation and U.S. Census Bureau, over 12.5 billion tons of freight, valued at $11.7 trillion, was carried over 3.3 trillion ton-miles in the United States in 2007. In particular, CFS data shows commodity flow growth exceeded growth of domestic product (GDP) in each time period of 1993, 1997, 2002 and 2007, and dependence on interstate flows had remarkably increased over the last decade. In addition to the increased interregional trade, the structure of interregional trade has been changing and becoming more complex.

In order to explain the transforming structure and system of interregional trade, the nature of economic interaction as well as the relevant processes across different levels of geographic space need to be explored. The clearer definition of the relationship between firm and establishment should be made first to understand the changes in spatial production organization observed in recent years. In the past, the majority of firms comprised one or at most two establishments. However, nowadays, multi-establishment firms are common. The effect of mergers and acquisitions together with the usual processes of entry and exit have promoted the present of multi-establishment firms in recent years (Parr *et al.*, 2002). With this changing system, new ownership patterns are observed that a firm owns its diverse constituent establishments. More importantly, the various establishments owned by a firm are located in an extensive state, multi-states and even international boundaries. The decreased transportation costs, advanced technology in communications and changing system of production have promoted this change in the spatial organization of firms. Therefore, it is important to investigate what is actually produced within the establishments, how and where inputs are sourced and output products are distributed to the market within the transformed spatial organization of production to understand the changing structure and system of interregional trade. At the level of individual establishment, its product level is smaller, returns to scale are higher, while returns to scope and complexity are lower, and the dependence on local suppliers and markets is reduced. Thus, it leads to a decrease in the metropolitan multiplier without a concomitant decrease in the production level. However, at the level of the firm, returns to scale, scope and complexity are higher, with the various products produced by the firm spread over establishments as part of a multi-state operation, leading to increases in interstate or interregional trade and thus increased in interstate or interregional dependence (Parr *et al.*, 2002).

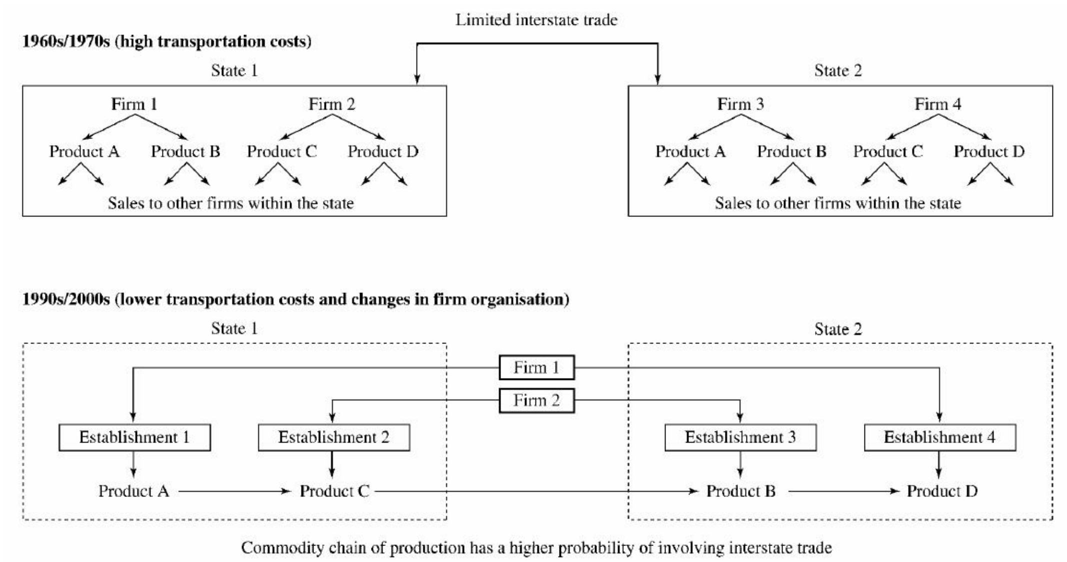

Figure 1-1. Changing spatial organization of firms (from four firms to two firms/four establishments)
Source: Parr *et al.*, 2002

Israilevich & Mahidhara (1991) and Hewings *et al.* (1998) detected that while output in most sectors was increasing for the period 1970-1987, and 1975-2011, respectively, in the Chicago region, the degree of interdependence was decreasing. This process was referred to earlier as 'hollowing-out' by Okazaki (1987), and implies a relative decrease in the density of intermediate transactions. In other words, firms are buying less from other firms within the region and selling less within the region. Hence, firms have to make a wider geographical search for their new sources of inputs and markets for their products; as a result, more interstate trade takes place. Technical change, price changes or changes in the competitive position of the economy can be attributed to this increasing gap between local production and local supply. However, it is apparent that this change might yield more increased interregional trade along with the more extensive interrelatedness or structural richness.

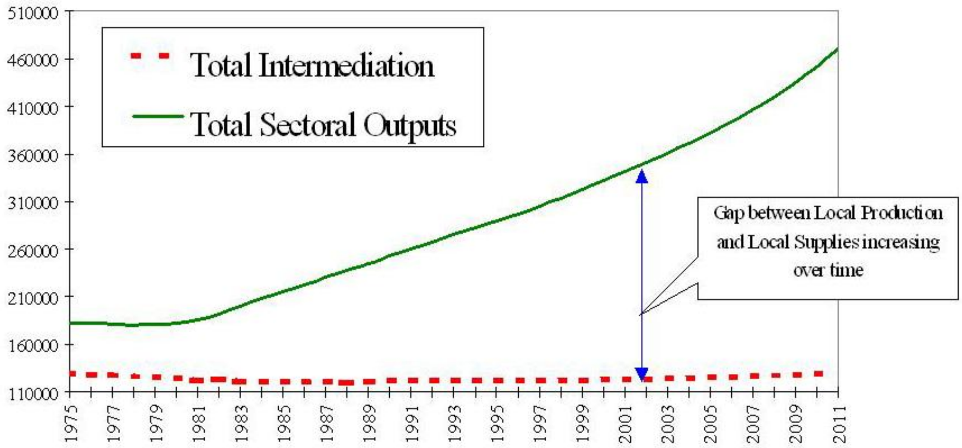

Figure 1-2. Values of total sectoral outputs and total intermediation in the changing economy, 1975-2011
Source: Hewings *et al.*, 1998

Another challenging and significant change in production structure is represented by fragmentation of production process. The whole production process has been fragmented into smaller and more specialized production components. Hence, each specialized sub-production process can be occurred in a separate locale with spatially specialized economy. The result of this new mechanism in the production process is that the value change of commodity chain now involves more interstate or interregional movements. In particular, more vertical intra-industry trade between smaller and more specialized production components are expected. The service links such as transportation infrastructure and communication networking have encouraged the production process more fragmented and vertically integrated each other.

All these process also have led to changes in the nature of trade. Several trade studies (Hewings *et al.*, 1998; Munroe *et al*., 2006; Seo *et al.*, 2004) in Midwest noted that interstate trade flows have grown rapidly as well as pointed out that the composition of interstate trade has changed with inter-industry interstate trade being replaced by intra-industry interstate trade. In addition, the proportion of intra-industry trade, as opposed to inter-industry trade, to the whole interstate trade is increasing. It can be explained by more specialized industries: On the one hand, as firms are producing different variety within the same industry to meet the taste of consumers who love different product variety by exploiting the economies of scale, more "horizontal" intra-industry takes place. On the other hand, greater "vertical" intra-industry trade occurs as firms are exploiting scale economies in specific establishments at the same time transporting intermediate products at various stages of the production process across the region before the products are delivered to next production stage as an input or to final consumers under the vertically integrated economies.

Based on several previous research works on U.S. Midwest states and Chicago metropolitan area as well as all observed trade patterns from the recent trade data raise some questions related to trade patterns and its spatial structure for the entire United States: *Where are the sources of inputs and markets for the producers in each state? Have there been any changes in the spatial* *pattern and structure of their interstate trade flows and why are they occurring?* Finally, *to what extent is the trend beneficial to each region?*

The dissertation explores the spatial economic interdependence based on interstate or interregional trade in the United State for recent years between 1992 and 2007. The analyses investigate the spatial pattern and nature of the interstate commodity flow for the first to find any changing spatial pattern of interstate trade reflected by changing of spatial production organization. Secondly, it examines the role of interregional trade in generating and distributing the regional economic growth at the same time the extent of its impact on regional economy. The last analysis focused on the spatial and sectoral linkages of U.S. regional economy. Hence, this last one figures out how each region is interrelated each other from the viewpoint of production system and how they are complementary or competitive in the whole regional economic context.

In the rest part of this chapter (section 2 of chapter 1), a general literature review of research on interregional trade and spatial interdependence, intra-industry trade, and the impact of trade on regional economy is provided. Chapters 2, 3 and 4 draw on main analyses to answer the research questions posed as above: *spatial pattern of the U.S. interstate commodity flows, the role of interregional trade in the U.S. economy,* and *spatial economic interdependence in the U.S. regional economy.* Chapters 2 to 4 unfold its own specific research objectives and detailed approach to analysis with certain data set, and describe the major findings in detail, respectively. As for the some terminology matters, Chapter 2 utilizes “interstate trade” because the chapter deals with U.S. commodity flow data among each U.S. state. In the other hand, Chapters 3 and 4 employ the term of “interregional trade” since these two chapters are based on the data that comes from U.S. six-region interregional input-output system instead of the data for each individual U.S. state. Finally, Chapter 5 concludes this dissertation by highlighting major findings from each analysis in each main Chapters 2 to 4 and put some emphasis on the implications this dissertation offers. This final chapter also lays out some future challenges.

2. Theoretical background

To develop an appropriate framework for analyzing interregional trade, this section begins with a brief review of the main trade theories from neo-classical ones to the new trade theory. Then, the major topics pertinent to interregional trade become the certain of attention, focusing on the nature of interregional trade. This section also reviews theoretical frameworks for the analysis of intra-industry trade from two different points of view: horizontal intra-industry trade *vs* vertical intra-industry trade. These first two parts support Chapter 2 as well as help comprehend the initial motivations and the whole picture of this dissertation. The third part reviews briefly the studies that emphasized the role of interregional trade in regional economic growth within the input-output analysis context. Each region within a regional economy is important as an economic space and its economic connection based on interregional interaction might play a key role to distribute the regional economic growth. Chapter 3 evaluates the role of interregional trade in U.S. regional economy by utilizing a decomposition technique that sort the interregional trade coefficient effect out from the composite interregional coefficient. The literature review concludes with introduction to the spatial economic interdependence studies based on the interregional input-output approach. Among several methods and techniques, chapter 4 adopts a combined hypothetical extraction method to explore the spatial economic interdependence in the U.S. regional economy by assuming several sets of worst-case scenarios.

2.1. Trade theories: Old, new, and the current

The Ricardian trade theory introduced a concept of "comparative advantage" to explain trade. It concluded that every nation should specialize in the production in which it had a comparative production cost advantage, allowing each nation to trade with others that had specialized in other types of production so that ultimately all nations would enjoy benefits from their specialization. However, the Ricardian trade theory cannot explain what determines comparative advantage and how trade affects the income distribution within a country. Heckscher's (1919) early ideas were refined by Ohlin (1933) to develop what is now referred to as the Heckscher-Ohlin theory (H-O theory), so-called factor abundance model. The H-O theory accounts for trade based on factor endowments: a country exports those goods that make intensive use of its most prevalent production factor. Vanek (1968) extended the H-O theory to a multi-good and multi-factor case. This extended theory is called now the HOV theory, which allows the analyst to focus on implicit trade in factor services. Beginning in the 1970s, some economist began to question the extent to which economic approaches to trade helped to explain what was actually happening in the real world; for instance, countries with very similar factor endowments or similar technology levels tended to trade the most with each other, which is not exactly what comparative advantage-based theories would suggest (Black, 2003).

Krugman (1979) developed the New Trade theory to explain why trade occurred in the first place and to provide a better explanation for the specialization and trade between regions. The New Trade theory does not depend on comparative advantage for explaining trade; the key to understanding the rationale for trade in Krugman's model in 1979 is the combination of increasing returns to scale at the firm level and the love-of-variety effect in consumers' preferences. The introduction of increasing returns to scale implies a market structure of imperfect competition. In Krugman's (1979) model, little is said about the role of geography: the location of economic activity is not really an issue. Firms are indifferent about the location of their production sites since trade costs are zero. Even if there were positive trade costs, the market size is evenly distributed between two countries, which precludes any agglomeration of economic activity. It is indeterminate which country ends up producing which varieties. All one can say is that countries produce different varieties and the pattern of trade is indeterminate. Krugman (1980) developed the 1979 model keeping the same rationale for intra-industry trade but employing several different assumptions: 1) the opening up of trade does not lead to an increase in the scale of production, instead, more varieties under trade than under autarky, 2) transport costs exist, which is obviously relevant from a geographical point of view, 3) demand per variety is no longer symmetric as countries differ in market size. However, even this 1980 model excluded formal consideration of the geographical location because neither firms nor workers decide anything about location in the model, and the allocation of market size for the varieties is simply given. Krugman and Venables (1990) refined previous models more by allowing countries to differ in size. Now the model deals with the agglomeration of economic activity better by means of introducing an uneven overall distribution. The New Trade theory is concluded to have three main issues that make it different from the Old Trade theories: increasing returns (economies of scale), imperfect competition, and a large size of the domestic market (Krugman, 1996).

2.2. Nature of interregional trade

Most trade research in the past has less interest in the spatial dimensions of trade as already summarized in the above section. Frankel (1998) noted that (international) trade theorists and researchers have ignored the geographical dimension so that they treated countries as disembodied entities that lacked a physical location in geographical space. The reawakened interests in the geographical dimensions of trade have focused attention on the factors that influence the amount and type of commodities shipped between regions, paying special attention to the nature of interregional trade. This section begins with some introduction in the study on spatial pattern of interregional trade, and then draws more details on one notable observation related to the nature of transforming interregional trade, which is dominantly increasing intra-industry interregional trade.

2.2.1. Spatial pattern of interregional trade

Studies on trade flows or commodity flows in the field of transportation geography or regional science can be categorized into three main subjects or approach. The first category focuses on the exploratory spatial data analysis of the flows. This realm is associated with several quantitative approaches in order to analyze the geographical or spatial patterns with indices based on mathematical or statistical methods with the goal of depicting the detected phenomena in the context of geography in more effective ways. The second category has endeavored more to detect and sort out the underpinning reasons or factors to determine the observed spatial pattern or structure of trade flows. For this division, various spatial interaction modeling approach have been developed. While the first approach only portrays the observed phenomenon, the second approach tries to discover what kind of forces determines the observed patterns or structure in the space. However, the second field can be developed based on the results extracted from the first category of analysis. The final topic is the estimation of trade flows; this third field is very much dependent on some of the findings and insights generated from the second field. Reliable estimation or forecast for the trade flows can be possible through the development of spatial interaction models that explain the reality in a plausible way. After all, the exploratory spatial data analysis on trade flows, which is categorized as the first subject in the field of interregional trade study, can be considered the cornerstone for understand the underlining regional economic structure. The objective of this chapter is in this first category of trade analysis. Therefore, this section summarizes the earlier research works only in terms of the exploratory spatial flow data analysis.

Map presentations of commodity movements have been the most common tools for transportation geographers and regional scientists to examine the pattern of trade flows among regions (Ullman, 1957; Smith, 1964; Cox, 1965; Berry, 1966; Rodgers, 1971; Tobler, 1975, 1981, 1987). Ullman (1957) examined the spatial pattern of commodity flows in U.S. domestic and foreign trade mainly through railroads in order to explain the spatial connections in the U.S. economy. He illustrated a series of maps demonstrating state-to-state freight movements of selective commodities for twenty representative states based on the Carload Waybill Statistics for the year of 1948 published by Interstate Commerce Commission. A study of the state-to-state trade flow maps enabled him to capture specialized production and consumption areas and the effect of distance on spatial interaction between regions. In this landmark study of his on the US commodity flows, Ullman explains flow as being determined by complementarity, intervening opportunity, and transferability. According to his three bases of spatial interaction, trade takes place when there are two regions providing a market clearing demand and supply of a shippable product (complementarity), when there is no other alternative source of supply (intervening opportunity), and when transport costs or friction is not too great (transferability).

Several studies on spatial interaction between regions had been built on Ullman's ideas are introduced in the followings.

Smith (1964) examined the agricultural commodity flow by rail to the six New England states in the U.S. in 1959. He devised an index based on one of Ullman's notions of spatial interaction, 'complementarity' to depict the spatial pattern of shipments of agricultural commodities to New England from 34 states. His index of complementarity indicates the relative importance of trading partners. Knudsen (1988) also utilized Ullman's concept of complementarity to analyze the pattern of trade partnerships in the U.S. interstate commodity flows for the period 1972 to 1981, and revealed that trade partnerships had been predominantly stable over time despite rapidly fluctuating flow volumes. Further, he concluded that partnerships involving large volumes are much more stable than those involving small volumes.

Berry (1962; 1966) introduced factor analysis to the field of flow analysis. Berry (1966) conducted a study on the Indian commodity flows to depict the pattern of flows as well as to identify the factors determining the pattern of connections within the Indian economy. First, he started by illustrating the spatial patterns of commodity flows in India. His study produced a large volume of maps of Indian commodity flows that provides a vivid cartographic portrayal of the principal patterns of spatial interaction in India in 1960. This atlas of Indian commodity flows covers 63 commodity items shipped within India. For each commodity, a set of maps contains twelve characteristics indicating shipment quantity and value of flows to or from main metropolitan centers (Calcutta, Bombay, Madras, and Delhi) as well as non-metropolitan areas, major producing areas, main transportation routes, major origins and destinations in the trade partnership, major regional flows and hinterland, and urban population density as a potential demand factor. Although such descriptive maps provide a quick glimpse of the pattern of commodity flows, more detailed and supplementary measures are required to enrich the studies of trade flows among regions in the field of transportation geography and regional science. Hence, Berry (1966) employed a general field theory-based analysis on relationship between commodity flows and spatial structure. To accomplish this analysis, dyadic factor analysis with a flow data matrix of 1,260 rows (36 by 36 for 36 major trade blocks) and 63 columns (for 63 commodity items) were made. Black (1973) also conducted dyadic factor analysis of a series of 24 commodity groups for the nine U.S. census divisions. He detected five significant factors and discovered each of these was centered on a different geographic region. Factor analysis of commodity flow data may be basic in any description of the geography of interregional flows for a set of regions.

Recent efforts have been made in applying the exploratory spatial data analysis on the interregional trade. Perobelli and Haddad (2003) employed LISA (Local Indicators of Spatial Association) statistics to explore the spatial distribution of the interregional trade among the 27 Brazilian states for years of 1985~1996. They detected the presence of spatial heterogeneity in the interregional trade during the period of analysis. Based on this result, they concluded that the regional disparities in Brazil have persisted over time.

Compared to the field of interregional trade study, more work has been focused on interregional migration studies for analyzing the spatial pattern of interregional migration (see, for example, Plane & Isserman, 1983; Ellis *et al.*, 1993; Pandit, 1994; Plane & Mulligan, 1997; Rogers *et al.*, 2002). Although trade in goods and trade in people (migration) have different characteristics and motivations, similar approaches might be applicable since both interactions are produced based on human economic and social behavior.

These reviews on the previous literature on exploration of interregional trade pattern in the field of geography and regional science affirm the motivations of this study help make the objectives clearer. Chapter 2 replicates Berry's flow factor analysis and trade Gini index measures adopted from the field of interregional migration study to explore the spatial pattern of the U.S. interstate commodity flows across four different time periods. The analyses investigate the temporal changes in spatial patterns of trade flows in terms of spatial association in the distribution of interstate trade, trading partnership, and the spatial extent of trading zones over time.

2.2.2. Intra-industry trade

Neoclassical trade theories covering from Ricardian models to Heckscher-Ohlin model focus on the differences between regions (mainly "countries" because they are mainly based on international trade) to explain mainly the causes of inter-industry trade. Hence, they cannot predict or explain intra-industry trade, because in such models, there is no reason for countries to trade identical products. Consequently, a number of theoretical models of intra-industry trade have been developed. If a specific product for the market is being produced in one location to exploit economies of scale, rather than being spread over several establishments in different regions, we expect increasing "horizontal" intra-industry trade. On the other hand, when firms are exploiting scale economies in specific establishments and transporting intermediate products at various stages of the production chain across regions before being delivered to final consumers, greater "vertical" intra-industry trade can be observed. In the following two subsections, two different types of intra-industry trade will be summarized in terms of its nature and mechanism how and why to take place under two different conditions.

2.2.2.1. Monopolistic competitive economy and "horizontal" intra-industry trade

Models based on monopolistically competitive markets have been developed first to explain intra-industry trade. A monopolistic competitive economy produces differentiated intermediate or final products in some manner and their production involves scale economies. Consumers, whose demand structures are assumed to include a taste for variety, will purchase some of each good, and thus there is "horizontal" intra-industry trade[1], which is distinct from "vertical" intra-industry trade mentioned in the following section with the notion of fragmentation of production. Unlike classical theories, these models focus on the increasing similarities between regions rather than on factor endowment differences. The New Trade theory developed by Krugman offers explanation for why trade occurred in the first place and how regions specialize their economy to trade effectively. Exploiting increasing returns to scale and consumer's love-of-variety preferences are the main sources of explanation about the increasing interregional trade, particularly, more intra-industry trade. As economies become more similar and per capita income rises, consumers' preferences become more diverse. Thus, consumer goods become differentiated more by type or variety. As each region specializes in a certain variety of a good, incentives for trade arise. Hence, the intra-industry trade in the Krugman's models is defined distinguishably as "horizontal" intra-industry trade.

An extensive set of theoretical and empirical work mainly based on cross-sectional examinations on "horizontal" intra-industry trade has tried to achieve consensus on its determinants. They have focused on an industry's proportion of intra-industry trade on the basis of differences in region and industry infrastructure (Stone, 1997). Greenway *et al.* (1995) measured quality differentiation through price differences to explain the determinants of intra-

[1] Intra-industry trade mentioned in this subsection stands for "horizontal" intra-industry trade hereafter.

industry trade. Bergstrand (1990) used income-related and endowments-related variable to explain intra-industry trade. He found a strong relationship with standard income-related variables. Average capital/labor ratios are also significant, although the difference in capital/labor ratios is not the case. Another main stream of intra-industry trade study is to construct an appropriate measure of intra-industry trade. This is needed to test empirically the theoretical frameworks. They have focused on the bilateral share of intra-industry trade. Grubel and Lloyd (1975) proposed a measure of intra-industry trade which is calculated by adjusting the overall share by multiplying by factor representing overall trade imbalance. Grubel-Lloyd index is measured as:

$$SIIT_{jk} = 1 - \left[\frac{\sum_i \left| X_{jki}^e - M_{jki}^e \right|}{\sum_i \left(X_{jki}^e + M_{jki}^e \right)} \right] \text{ where, } X_{jki}^e = X_{jki} \left[\frac{\left(X_{jk} + M_{jk} \right)}{2X_{jk}} \right], \; M_{jki}^e = M_{jki} \left[\frac{\left(X_{jk} + M_{jk} \right)}{2M_{jk}} \right]$$

X and *M* denote exports and imports respectively, and *j* and *k* are two trading countries, and *i* is the industry. This index displays the level of trade within an industry relative to trade between industries. A value of 1 would imply perfect trade overlap, or that the value of that region's exports from a given industry is equal to the value of imports to that same industry. A value of 0 would imply perfect specialization within that industry, that the value of either exports or imports is equal to zero.

2.2.2.2. Fragmentation of production and "vertical" intra-industry trade

Hummels, *et al*. (1998) postulated that the internationalization of production led to vertically linked economies. More recently, an important empirical study by Ng and Yeats (2003) showed that East Asian imports and exports of manufactured parts and components grew annually between two and three times as fast as imports and exports of traditional production between 1984 and 1996. Such rapid growth of trade in parts and components has been explained in several terms – production outsourcing, international fragmentation, and the emergence of international production networks (Yeats, 2001; Ng and Yeats, 2003; Jones and Kierzkowski, 2005). One main concept common to almost all explanations, but using various terms, is that production processes which traditionally have been vertically integrated within a firm or within a region have become fragmented into separate parts that can be located in several different locations within a country or in different countries where factor process are well matched to the factor intensities of the particular production fragments. In this framework, regions specialize in a particular stage of the production process, leading to increased "vertical" intra-industry[2] trade as production increases. In this definition of vertical specialization, a good must be produced in multiple sequential stages, and must cross at least one regional border more than once. For example, in the simplest form, one country can export an intermediate good to another country that completes production of the good, and then exports the final product back to the first country. Hence, there appears to be another type of intra-industry trade, so-called "vertical" intra-industry trade, which mainly focuses on trade in intermediate goods under the vertical integration of production.

Jones and Kierzkowski (1990; denoted *JK* hereafter) presented for the first time a general framework to analyze international fragmentation of production, in which they described why fragmentation of production takes place and how it gives rise to international trade flows. In the simplified version of the *JK* fragmentation framework/model, production blocks may exhibit constant returns to scale, whereas the service link activities are assumed to exhibit increasing returns associated with fixed costs that are invariable to scales of output. Now, consider a

[2] Intra-industry trade mentioned in this subsection denotes "vertical" intra-industry trade hereafter.

particular final commodity produced in a vertically integrated production process with all activity taking place in one location. However, the total production costs might be lowered by outsourcing some fragment of the integrated production activity. In other words, moving one fragment which makes relatively intensive use of unskilled labor to another location where labor productivity is higher relative to its wage rate. Then, such a geographical separation of production fragments requires service links such as transportation, communication and other coordinating activities. If the extra costs of the service link activities are more than balanced by the lower marginal costs obtained by a closer match of factor intensities with net factor productivities for each fragment, outsourcing will take place in order to minimize production costs. For a given degree of fragmentation, the nature of service link activities leads to a drop in total average production costs as output increases. However, further increases in output may suggest a finer degree of production fragmentation. Then, the extra costs of service links are more than matched by the lower assembled marginal costs of the production blocks. In all, the average production costs decrease as output increases for a given pattern of fragmentation, and marginal costs of total production are lowered discontinuously at the point where the degree of fragmentation is increased (Jones and Kierzkowski, 1990). Figure 1-3 illustrates why and how fragmentation of production takes place as the output level increases. Line 1 from the origin depicts the production costs when the production is carried out in a single production block with constant returns to scale, while line 2 with vertical intercept $\overline{OA}$ suggests an alternative process whereby two different locations are selected to take advantage of geographic differences in various factor costs and productivities. The flatter slope of line 2 indicates that the combination of those two locations lowers aggregate marginal costs. However, the cost of service links is required by $\overline{OA}$ of its vertical intercept. This fragmentation becomes cost-effective when output levels exceed $\overline{OD}$. The other two lines, 3 and 4, illustrate two other cases where a firm is able to decrease marginal costs if it practices a greater degree of fragmentation of production process. Since fragmentation raises the costs of service links, line 4 has the highest intercept, $\overline{OC}$, representing the greatest cost of service links. As a result, an integrated minimum cost schedule is shown by the thick line in figure 1-3, which reveals that optimal behavior involves a selection of techniques that minimize the total costs of production, and this entails the greater degrees of fragmentation, leading eventually to outsourcing, as input levels increase to reach D, E, and F continuously. In conclusion, increasing degrees of fragmentation entail the total cost schedules that have higher vertical intercepts and lower marginal costs so that they intersect each other. Optimality is achieved if, for each level of output, the degree of fragmentation selected minimizes costs, and the resulting minimum-cost schedule exhibits increasing returns to scale. The more production blocks are fragmented the more "vertical" intra-industry trade is expected.

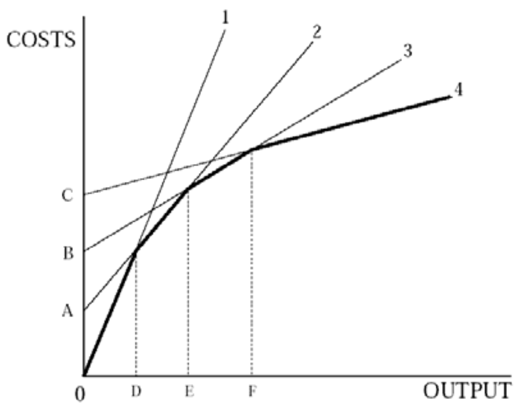

Figure 1-3. Costs and fragmented production
Source: Jones, *et al.*, 2005, p. 312

Various aspects of fragmentation have been investigated both theoretically and empirically. More concerns have been focused on its impacts on labor markets (Arndt, 1997; Egger and

Egger, 2005; Dluhosch, 2006) related to wage differential and labor market price, and other related welfare issues. Harris (1993; 1995) concentrated on the role of telecommunications in establishing a new production paradigm. The typical empirical studies on fragmentation are to explore the pattern of international trade in parts or components. Jones, *et al*. (2005) confronted the *JK* model with data on international trade in parts and components. This type of trade grew from $355 billion to $846 billion between 1990 and 2000, a rate of growth much higher than that of world GDP, and world trade in general. As predicted by the theory of production fragmentation and outsourcing, the main sources of this growth have been the world income expansion and the lowering of service links costs. Kimura and Ando (2005) pointed out that less control over production has a cost, and the calculus of fragmentation thus becomes more complex. One of their important findings is that Japanese manufacturing affiliates in East Asia tend to substitute arm's-length transactions for intra-firm transactions to outsource the production fragment for producing parts and components. It might be understood that the geographical proximity is still important as the cost of service links connecting each production block play a crucial role in production fragmentation. Hanson (1996) has illustrated the fragmentation phenomenon in the case of Mexico and its closer association with production in the United States. In this case, the geographical proximity might be one of the significant factors as well. However, it is doubtful whether this rule also works at interregional level trade.

2.3. Interregional trade and regional economic growth

The relationship between trade and growth has been a familiar topic of discussion in the development literature. In particular, a number of models that stressed the effects of international trade on economic growth have been developed. Torado (1994) noted that trade is an important stimulus to rapid economic growth, although it might not be a desirable strategy for economic and social development. He also concluded that the contribution to development depends on the nature of the export sector, the distribution of the benefits from trade, and the sector's linkages with the rest of the economy. Therefore, many efforts have already made to measure the effect of trade on economic growth. The most popular and common analysis conducted by many regional scientists for exploring the effect of trade on regional economic growth is multiplier analysis of the interregional economic dependency by incorporating input-output table into trade matrix (Miyazawa, 1960; Goodwin, 1983; Haddad, *et al.*, 1999). Hitomi *et al.* (2000) noted that interregional trade played a key role in determining the regional output level in Japan for 1980~1990. They constructed multiregional input-output models with nine regions and 40 sectors for Japan, and then used a decomposition method within this multiregional input-output framework. Haddad *et al.* (2002) explored trade gains and losses in a cost-competitiveness approach, based on relative changes in the industrial cost and demand structures. They integrated a Machlup-Goodwin-type interregional model into a national CGE (computational general equilibrium) model so as to analyze the effect of trade on the economies of each state in Brazil. Weinhold (2002) noted that economic space as well as geographic space is important as a possible medium through which growth rates are distributed across regions. She defined economic space in terms of economic connection based on bilateral trade flows to address the importance of trade on regional economic growth. Hence, there is an opportunity to explore the relevance of some of these ideas and frameworks in the context of interregional trade flows and their influence on growth. Chapter 3 assesses the role of interregional trade in determining the U.S. regional economic growth using a decomposition technique.

2.4. Spatial economic interdependence

The limitation of cartographical representations on maps inspired regional scientists to focus more attention on an interregional input-output (IRIO) or multiregional input-output (MRIO) models based on an input-output framework since either the IRIO or MRIO models facilitates the incorporation of information regarding trade flows between different sectors in different regions. Leontief (1953) devised the intra-national input-output accounts in which only net trade flows are specified for each sending region and sector, while Isard (1960) developed the IRIO accounts in which trade flows are fully specified by region and by sector.[3] However, the data required to link more than just a few regions in a true IRIO model could be enormous. For this reason, many-region IRIO models have seldom been implemented in practice. Instead, a less data-intensive and more practical MRIO has been more implemented. Polenske (1970; 1974) implemented the MRIO model to project output and interregional trade flows for regions and sectors.

The measurement of interindustry linkages has long been central to the field of input-output analysis. It is because input-output models are useful for analyzing the effect of changes in one sector on the others; using this system, it is possible to detect not only which sector is more important in a regional economy but how important the sector is in generating impacts on the rest of the economy. Exploiting the idea of backward and forward linkages, it is possible to analyze the effects of change on both the demand and supply sides. The backward linkage effects reveal the impacts of a demand stimulus on the other sectors in the region in order to satisfy intermediate requirements. Forward linkage view the impacts of a supply stimulus on regional

[3] This accounting structure is still used in Japan for their IRIO tables, which the Japanese have published once every 5 years since 1960, originally for 9 regions and 10 sectors.

production since it might induce the use of its output as an input for other production activities (Cella, 1984).

One of the most popular and traditional ways is to take the column sum of the input matrix *A* as a measure of the direct backward linkages (Chenery and Watanabe, 1958). To capture the indirect effect, the Leontief inverse $(I-A)^{-1}$ is usually employed. Key sector analysis based on this Leontief inverse and the concepts of backward and forward linkages identify the sectors that have the greater impact on the economic system. When the Leontief inverse is defined as $(I-A)^{-1}=L=\left[l_{ij}\right]$, the column, row and total sums of the matrix *L* are terms as $l_{\bullet j}$, $l_{i\bullet}$, and $l_{\bullet\bullet}$, respectively. Then the average of all elements of the matrix *L* as defined:

$$L^{*}=\frac{l_{\bullet\bullet}}{n^{2}} \tag{1}$$

Using this definition, Rasmussen (1958) and Hirschman (1958) proposed the calculation of the both backward and forward linkage indices, U_j and U_i as follows:

$$U_j=\frac{l_{\bullet j}/n}{L^{*}} \text{ and } U_i=\frac{l_{i\bullet}/n}{L^{*}} \tag{2}$$

where *n* is the number of sectors. When the former index is greater than 1, it means a unit change in final demand of sector *j* produces more than the average impact on the economy. When latter index greater than 1, it indicates that a unit change in all sector's final demand stimulates an above average increase in sector *i*. Combining these two indices, key sectors in an economy can be detected; a key sector has indices that both are greater than 1.

The notion of a field of influence, developed by Sonis and Hewings (1994), is another useful concept to explore the impacts of change in an economy. The underlying idea of the field of influence is to assess the changes in the Leontief inverse matrix resulting from the changes in one or more direct input coefficients in the inverse Leontief matrix. Hence, it is possible to evaluate whether the impact of a coefficient change is concentrated in one or two other sectors or more broadly dispersed throughout the entire economy.

Another approach to explain and analyze trade flows and spatial interdependence is a gravity type interregional commodity flow model. Isard (1954) suggested the possible use of gravity potential models in the analysis of trade flows, and Leontief and Strout (1963) developed a gravity type interregional commodity flow model. Later this approach has developed in various ways by replacing the gravity analogy by the more general concepts of entropy or information theory for modeling interregional trade flows as well as for replicating and estimating flows (Roy, *et al.*, 2004). The spatial interaction models are usually means of assessing short-term adjustments to the spatial structure of the supply system.

Hence, analyses of the spatial structure of economies within a regional system or regional economic interdependence among regions are more typical of studies pertinent to interregional trade in the regional science field. They have examined the interregional trade itself, but more from the perspective of interregional trade as an explanatory variable or factor to investigate the spatial economic interdependence or regional economic interconnectedness among regions. The pioneering studies that opened a new way to regional economic connectivity issues are a series of studies on interregional feedback effects by Miller (1966; 1986), which shed more light on intraregional interactions.

Khan and Thorbecke (1988) developed the structural path analysis to explore the spatial interdependence at a very micro level. On the other hand, feedback loop analysis is an approach extended Miller's concept of interregional feedbacks within the wider framework of feedback loops of economic self-influence (Sonis, *et al.*, 1995; 1997; 2001; 2002). Feedback loop analysis is a more meso-level approach, and reveals not only the magnitude of the flows but also the hierarchical structure. In addition, Miyazawa's extended input-output framework is also employed to analyze the spatial hierarchy of trade flow (Sonis & Hewings, 1993; Hewings, *et al.*, 2001). The internal and external multipliers extracted from the Miyazawa analysis can be used to show the degree of interregional interdependence based on the impact of trade flows.

Another interesting approach to understand the importance of interindustry linkages is the hypothetical extraction method originally proposed by Strassert in 1968 and developed further by Schultz (1976; 1977). The central idea of Strassert is to extract a sector hypothetically from an economy, and then measure the difference between the original output level and the output level with the sector removed from the economy. Based on this method, the total amount of this output decrease in the other sectors is calculated to measure the linkages and importance of the extracted sector. However, his method does not distinguish the total linkages into backward and forward linkages because it eliminates both the corresponding row and column of the sector from the input coefficient matrix (Cella, 1984; Dietzenbacher *et al.*, 1993; Dietzenbacher *et al.*, 1997; Perobelli *et al.*, 2003). Chapter 4 has an opportunity to explore the spatial economic interdependence among five Midwest and the rest of U.S. implementing the combined approach to hypothetically extract sectors as well as regions.

As summarized above, most of the theoretical and empirical studies have been from an economic point of view, with few geographical perspectives, and they have usually dealt with international trade not interregional trade. In many cases, this lack of attention to regional analysis may be attributed to the lack of data that makes more geographical location-specific or interregional-level studies available. Hence, this dissertation aims at exploring the issues related to trade and spatial economic interdependence at an interregional level from the geographical perspectives. First, this dissertation explores the geographical/spatial pattern of interregional trade based on commodity flow data across 48 states in the U.S. in chapter 2. Secondly, it assesses the role of interregional trade in generating the regional output change in the U.S. regional economy in chapter 3. Finally, it investigates the spatial economic structure of the U.S. economy in terms of their spatial and sectoral linkages within the context of interregional input-output analysis framework in chapter 4. For all these analyses, this dissertation utilizes U.S. regional level economic data such as U.S. interstate Commodity Flow Survey (CFS) data and the U.S. Multi-Region Interregional Input-Output Account data. The following three chapters describe all the details on the data and methodology of analyses, empirical findings of analyses, and some implications of study, respectively.

Chapter 2

Spatial Pattern of the U.S. Interstate Commodity Flows

1. Introduction

Commodity flows within the United States during 1993, 1997, 2002, and 2007 have been surveyed and compiled in a series of reports by the U.S. Census Bureau and the Bureau of Transportation Statistics. According to the four-year series of Commodity Flow Survey (CFS) reports, commodity flows over the entire United States have increased remarkably over the last 15 years, from 1993 to 2007 (Table 2-1). In particular, Table 2-2 shows commodity flow growth exceeded growth of domestic product (GDP) in each time period of 1993, 1997, 2002 and 2007.

Table 2-1. Total shipment of all the commodities, 1993~2007

Year	Value ($million)	Ton (thousand tons)
1993	5,846,334	9,688,493
1997	6,943,988	11,089,733
2002	8,397,210	11,667,919
2007	11,476,086	12,173,993

Data source: Bureau of Transportation Statistics, Commodity Flow Survey 1993, 1997, 2002 and 2007

Table 2-2. Comparison of growth rates of national GDP and commodity flows, 1993~2007

	Growth rates		
	Gross Domestic Product	Commodity Flows (value)	Difference in Percentage Points
1993-1997	15.54%	18.78%	3.23%
1997-2002	15.46%	20.93%	5.47%
2002-2007	14.68%	36.67%	21.99%
1993-2002	33.40%	43.63%	10.23%
1993-2007	52.98%	96.30%	43.32%

Data source: Bureau of Economic Analysis, Real Gross Domestic Product (chained dollars), 1990~2008
Bureau of Transportation Statistics, Commodity Flow Survey 1993, 1997, 2002 and 2007

Interregional trade has increased gradually as each region within a country and for the world as a whole have been rapidly integrating into one very open economy. Commodity flow reflects differences in regional economic structure as well as differences in the tastes and preferences of consumers. Nevertheless, very little work has been directed to exploring the spatial or geographical patterns of trade. Frankel (1998) noted that (international) trade theorists and researchers have ignored the geographical dimension so that they treated countries as disembodied entities that lacked a physical location in geographical space. This reawakened interest in the geographical dimensions of trade has focused attention on the factors that influence the amount and type of commodities shipped between regions, paying special attention to the nature of spatial interdependence. Hence, any trade analysis should begin by exploring the spatial pattern of trade.

A number of studies have already analyzed the spatial structure of trade patterns. However, most of these were conducted at an international level rather than an intra-national or interregional level. For U.S. interstate trade flows, no recent comprehensive studies have been completed. In the past (pre 1993), data on interregional trade was not published after 1966 but there has been continuing interest in understanding how regions are connected and the nature, strength and spatial structure of these dependencies. Some attention has been focused on the pattern of interstate trade among five major Midwest states, including Illinois, Indiana, Ohio, Michigan, Wisconsin; the results revealed that trade flows among these states had increased and intra-industry interregional trade has replaced the inter-industry interregional trade as the dominant set of flows (Hewings *et al.*, 1998b; Munroe *et al.*, 2007). Still, it is not easy to find a comprehensive study on the commodity flows or trade flows among states in the entire U.S. Even though the data sets are not perfect, the CFS data are planned to be collected every five years henceforth. The current four-observation series of commodity flow survey data makes it possible to explore and analyze the spatial patterns of interstate trade flows in the U.S. over time. According to CFS data, interstate trade shipments in the entire U.S. have also increased since 1993. It is expected that some inconsistent details might exist when looking into the entire U.S. compared to the study only focused on the Midwest. A study on the entire U.S. interstate trade offers the possibility to test existing trade theories or models as well as previous empirical studies in a broad context.

The present study will investigate the spatial pattern of interstate trade flow in the entire inland U.S. It focuses on the geographical dimension of interstate trade exploring the spatial structure of the trading pairs among 48 U.S. states across four different years, 1993, 1997, 2002 and 2007. The objective is to seek answers to the following research questions:

1) Have there been any changes in the spatial pattern and structure of the U.S. interstate trade flows in terms of spatial concentration or spatial dispersion over time?
2) Where are the sources and markets of each state with the U.S. interstate trade system? To what extent have the trading partnerships changed among the 48 states over time?
3) Which state or region is more dominant in the trade hierarchy in the U.S. interstate trade system and how has this changed over time?

Section 2 describes the Commodity Flow Survey data as a main data this study utilizes and explains the methods adopted for the exploratory spatial data analysis on the U.S. interregional trade system, using two approaches: trade Gini index measurement and trade flow matrix factor analysis. Section 3 reports the empirical results from the analyses on the 48 by 48 origin-to-destination U.S. interstate CFS for four different years. The final section summarizes this study with the empirical findings and some directions for the future research needs.

2. Data and methods

2.1. Commodity Flow Survey (CFS) data

The U.S. commodity flow data, which is based on the 2007 Commodity Flow Survey (CFS) conducted by the Research and Innovative Technology Administration (RITA), Bureau of Transportation Statistics (BTS), and the U.S. Census Bureau, U.S. Department of Commerce, has been released recently in December 2009 and thus provides the fourth set of data on the movement of goods in the United States.

Table 2-3. Comparison among datasets of CFS 1993, 1997, 2002 and 2007

	1993	**1997**	**2002**	**2007**
Geographical coverage	50 states & D.C. 89 NTARs[1]	4 Census Regions 9 Census Divisions 50 states & D.C. Selected Metropolitan Areas		
Industry coverage	Based on 1987 SIC[2]	Based on 1997 NAICS[3]		
Commodity classification system	STCC (33 commodities)[4]	SCTG (41 commodities)[5]	SCTG (41 commodities)[5]	SCTG (41 commodities)[5]
Transportation mode*	17 modes[6]	13 modes[6]	13 modes[6]	13 modes[6]
Sample size	About 200,000 establishments	About 100,000 establishments	About 50,000 establishments	About 100,000 establishments
Additional special reports	None	Export Hazardous Materials	Export Hazardous Materials	Export Hazardous Materials

1) National Transportation Analysis Regions defined in a basis of the Bureau of Economic Analysis regions
2) Standard Industry Classification
3) North America Industry Classification System
4) Standard Transportation Commodity Classification; number in the parenthesis is based on 2-digit SCTG code
5) Standard Classification of Transported Goods; number in the parenthesis is based on 20digit SCTG code; from the 2002 CFS, retail electronic shopping and mail-order houses are newly added
6) excludes "other and unknown modes"; figures include the number of single modes as well as multiple modes

Note: Author summarized based on overview information for each CFS report

This study utilizes all the sets of commodity flow data based on the CFS since 1993 to identify the geographical patterns of U.S. interstate commodity flows over time, for 1993, 1997, 2002 and 2007. The CFS data provides information on shipment characteristics such as type, value, weight, distance, origins and destinations, and transportation modes for commodities shipped in the 50 states and the District of Columbia (D.C.). These state-to-state commodity flow movement information has been commonly used for regional transportation-related research and policy making although there are a couple of inherent problems. One main limitation is that some parts of the interstate commodity flow information in CFS data are not disclosed due to an unacceptably high statistical variability and the resulting lack of confidence in the estimate. The other one would be due to the limited industry coverage of the survey. While the CFS covers shipments originating from mining, manufacturing, wholesale, and selected retail and services trade industries, commodity shipments from farms, fisheries, transportation, construction, and most government-owned establishments and many other retail and services industry-related establishments are excluded from the CFS. In order to overcome these limitations, the Office of Operations, Freight Management and Operations of the Federal Highway Administration (FWHA), U.S. Department of Transportation (USDOT) funded the Freight Analysis Framework (FAF) project, which developed a technique that fills gaps in the U.S. commodity flow matrices provided by CFS 2002[4]. However, the present study is based on CFS data instead of FAF^2 data since its main objective is to explore the spatial shifts in the U.S. interstate commodity flows between 1993 and 2007; this would not be possible with the FAF data. This study focuses on 48 U.S. states that exclude Alaska and Hawaii. This study aggregates the given commodity categories in CFS into 13 groups that still preserves more detail in manufactured goods.

[4] The FAF project constructed the U.S. commodity flow matrix mainly based on CFS 2002 and any other commodity flow datasets offering national, commodity specific, and mode specific coverage by employing two principal methods: the log-linear modeling and iterative proportional fitting (IPF) routines. The project produced the FAF 2002 U.S. Commodity Origin-Destination Database (FAF^2), which is comprised of three four-dimension matrices for tons, value, and ton-miles, in which the four dimensions are origin, destination, commodity, and mode.

Table 2-4. Commodity classification for CFS analysis in this study

code	Sector description	SCTG (1997, 2002, 2007)	STCC (1993)
01	Agriculture, Forestry and Fisheries	1-4, 25	1, 8-9
02	Mining	10-16	10-11, 13-14
03	Construction	None	None
04	Food, Beverage, and Tobacco Products	5-9	20, 21
05	Textile, Apparel, and Leather Products	30	22, 23, 31
06	Paper and Printing Related Products	27, 28, 29	26, 27
07	Chemical and Allied Products	17-24, 31	28-30, 32
08	Primary Metals Products	32	33
09	Fabricated Metal Products	33, 38	19, 34, 38
10	Industrial Machinery and Equipment	34	35
11	Electronic and Electric Equipment	35	36
12	Transportation Equipment	36, 37	37
13	Wood, Furniture & Misc. Manufacturing Products	26, 29, 40	24, 25, 39
14	TCU, Services, and Government Enterprises	41, 43, 99	40, 41, 42, 48, 99

Note: No commodities shipped in the sector of construction (03)

All the analyses in this study are basically conducted for all aggregated commodities and with greater attention to the values of shipments. However, the analysis based on tonnage of shipment will be conducted to enhance the insights in the pattern and structure of flows. Further, some selected commodity groups are also considered for the deeper analysis. Related to the commodity-specific flows, selected manufactured goods such as chemical products and food, beverage and tobacco products explain the large part of the whole comprehensive flows. Another selected commodity group is the goods from mining industry since this commodity group also accounts for a large amount of shipments in terms of value as well as weight. For instance, chemical products and food-beverage-tobacco products account for over 30% of the values of all commodity shipments (24.1% and 8.8%, respectively), and mining products comprise 30.1% of all tons shipped among 48 U.S. states in 2007.

Table 2-5. Value of shipment by commodity group, 1993, 1997, 2002, and 2007 (unit: million $)

	1993		1997		2002		2007	
commodity	Value	Rank	Value	Rank	Value	Rank	Value	Rank
01	125762	11	187157	11	114311	11	251953	11
02	41321	12	47100	12	36576	12	79037	12
04	855005	2	650620	3	590903	3	1005265	2
05	351666	6	302927	9	312562	7	348722	10
06	185720	10	353553	7	242567	9	358588	9
07	1017600	1	1156792	1	1234678	1	2765197	1
08	206116	9	251882	10	198434	10	432696	8
09	371532	4	323361	8	294230	8	564295	6
10	360360	5	363248	6	360486	6	555574	7
11	348926	7	734938	2	602977	2	879577	3
12	502301	3	527563	5	557228	4	788757	4
13	569522		301503		491624		708510	
14	71708		650620		590903		917136	

Note 1: Only 48 U.S. states are considered for calculations.
Note 2: For the rankings, sector 13 and 14 are excluded since their composition characteristics.
Data source: Bureau of Transportation Statistics, Commodity Flow Survey 1993, 1997, 2002 and 2007

Table 2-6. Tonnage of shipment by commodity group, 1993, 1997, 2002, and 2007 (unit: thousand tons)

	1993		1997		2002		2007	
Commodity	Ton	Rank	Ton	Rank	Ton	Rank	Ton	Rank
01	525984	4	966203	3	504135	3	790010	3
02	2602296	2	3101830	1	2768892	2	3668875	1
04	832836	3	575422	4	494483	4	703793	4
05	35334	9	39028	11	33054	10	34252	11
06	199341	6	244023	6	162365	6	226173	6
07	2853626	1	2813131	2	2770650	1	3561016	2
08	245258	5	286966	5	224704	5	304608	5
09	84318	7	83176	8	66089	8	106093	8
10	28521	10	41608	9	43457	9	52910	9
11	25811	11	33085	11	28375	11	34675	10
12	74235	8	83950	7	87796	7	116984	7
13	99585		219074		295300		387396	
14	656793		338235		312856		384718	

Note 1: data calculated for 48 U.S. states
Note 2: ranking for sector 13 is not considered
Data source: Bureau of Transportation Statistics, Commodity Flow Survey 1993, 1997, 2002 and 2007

2.2. Exploratory spatial data analysis of interstate commodity flows

2.2.1. Gini index of concentration in an interstate trade system

The Gini coefficient[5] is one of the most common indices to measure income distribution in economics. This section adopts this Gini index to explore overall shifts in the geographical patterns of flows in terms of "spatial concentration" or "spatial dispersion" in an interstate trade system based on Plane and Mulligan (1997). They introduced the methods based on the Gini coefficient in order to gauge the degree of spatial inequality that exists in the relative volumes of a set of origin-destination-specific flows in the U.S. interstate migration system. Using the Gini index measures, they compared the degree to which the sources of in-migration versus the destinations of out-migration are spatially focused for the U.S. migration movements in the 1980's. This section replicates their application of Gini indices to explore the shifts in the overall geographical patterns of flow in the U.S. interstate trade system for 1993~2007[6]. Several sets of the Gini index are calculated in this section to show the spatial concentration of importing or exporting states in the U.S. interstate commodity flow movements. A total Gini coefficient for a commodity *m*, ${}^{T}G(m)$, is first calculated based on gross commodity flows among 48 states (*n*=48) excluding intrastate movements (flows within a state) as (1):

[5] For a set of n numbers of observations, a general formula of a Gini index is defined as:

$$G = \frac{\left[\sum_{a=1}^{n} \sum_{b=1}^{n} \left| y_a - y_b \right| \right]}{2n^2 \mu}$$

where y_a, y_b represent two of different observations, and μ is the mean of all n numbers of observations.

[6] For the detailed method explanation, see Plane & Mulligan (1997).

$$ {}^{T}G(m) = \frac{\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}\sum_{g=1}^{n}\sum_{\substack{h=1\\ h\neq g}}^{n}\left| f_{ij} - f_{gh} \right|}{2\left[n(n-1)\right]^{2}\left[\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} f_{ij}\right] T/[n(n-1)]} = \frac{\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}\sum_{g=1}^{n}\sum_{\substack{h=1\\ h\neq g}}^{n}\left| f_{ij} - f_{gh} \right|}{2\left[n(n-1)\right]T} \quad (1) $$

where f_{ij} = commodity flows from state i to state j (i, j=1,⋯,48)

$T = \sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n} f_{ij}$: total interstate commodity flows between two different states

The second three sets of interstate trade Gini index measure the spatial equality of the total commodity flows divided into three components: gross outflows, gross inflows, and net trade exchanged among states. Gross outflow Gini index for commodity m, ${}^{T}G_{R\bullet}(m)$, is calculated as the differences between interstate commodity flows leaving a same origin state (by row in a state-to-state commodity flow matrix) so as to show the relative extent to which the destination selections of commodity outflows of each state are spatially focused in the entire trade system as the equation (2):

$$ {}^{T}G_{R\bullet}(m) = \frac{\sum_{i=1}^{n}\sum_{\substack{j=1\\ j\neq i}}^{n}\sum_{\substack{h=1\\ h\neq i,j}}^{n}\left| f_{ij} - f_{ih} \right|}{2\left[n(n-1)\right]T} \quad (2) $$

The Gini index of gross inflows for commodity m, ${}^{T}G_{\bullet C}(m)$, is also calculated in a similar way as above, but based on the differences between interstate commodity inflows to a same destination state from various origin states (by column in a state-to-state commodity flow matrix). The gross inflows Gini index is calculated based on equation (3) and represents the degree of spatial concentration of commodity flows from all the various origins.

$$ {}^{T}G_{\bullet C}(m) = \frac{\sum_{j=1}^{n} \sum_{\substack{i=1 \\ i \neq j}}^{n} \sum_{\substack{g=1 \\ g \neq j,i}}^{n} \left| f_{ij} - f_{gj} \right|}{2\left[n(n-1)\right]T} \tag{3} $$

The exchange Gini index, ${}^{T}G_{RC,CR}(m)$, is calculated based on the difference between each commodity flow (f_{ij}) and its counterpart's flow (f_{ji}) following the formula in (4):

$$ {}^{T}G_{RC,CR}(m) = \frac{\sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} \left| f_{ij} - f_{ji} \right|}{2\left[n(n-1)\right]T} \tag{4} $$

The index varies from 0 to 1. The Gini index is equal to 0 when all commodity movements are evenly distributed among all possible origins and destinations. An index of 1 indicates that all movements are concentrated in a single interstate trade flow, which means that there is only one dominant origin producing all outflows or there exists only one destination absorbing all inflow shipments. When a comparison among indices over time is needed, using *t* to denote the time period, standardization is possible by dividing each Gini index value by the total flow Gini index value to facilitate comparison among indices over time. The relative values obtained through (5) can tell us whether outflow or inflow or net exchange is more spatially focused in an entire interstate trade system over different time periods.

$$ \begin{aligned} &{}^{T}G_{R\bullet}{}^{*}(m)_t = 100 \times {}^{T}G_{R\bullet}(m)_t \,/\, {}^{T}G(m)_t \\ &{}^{T}G_{\bullet C}{}^{*}(m)_t = 100 \times {}^{T}G_{\bullet C}(m)_t \,/\, {}^{T}G(m)_t \\ &{}^{T}G_{RC,CR}{}^{*}(m)_t = 100 \times {}^{T}G_{RC,CR}(m)_t \,/\, {}^{T}G(m)_t \\ &{}^{T}G_{R\bullet}{}^{*}(m)_t + {}^{T}G_{\bullet C}{}^{*}(m)_t + {}^{T}G_{RC,CR}{}^{*}(m)_t + {}^{T}G_{Other}{}^{*}(m)_t = 100 \end{aligned} \tag{5} $$

where
$$ \begin{aligned} &{}^{T}G_{Other}(m)_t = {}^{T}G(m)_t - \left[{}^{T}G_{R\bullet}(m)_t + {}^{T}G_{\bullet C}(m)_t + {}^{T}G_{RC,CR}(m)_t \right] \\ &{}^{T}G_{Other}{}^{*}(m)_t = 100 \times {}^{T}G_{Other}(m)_t \,/\, {}^{T}G(m)_t \end{aligned} $$

The last two sets of Gini indices introduced by Plane and Mulligan (1997) are more relevant since they decompose the gross outflow and inflow Gini indices further so as to facilitate the examination of the contributions of each state to the entire system. The two additional more disaggregated indices are defined as the outflow field Gini index, ${}^{O}G_{k\bullet}(m)$ and the inflow field Gini index, ${}^{I}G_{\bullet k}(m)$ for commodity *m*, respectively. Each field Gini index can be computed employing the formulas in (6):

$$
\begin{aligned}
{}^{O}G_{k\bullet}(m) &= \frac{\sum_{\substack{j=1 \\ j\neq k}}^{n}\sum_{\substack{h=1 \\ h\neq k}}^{n}\left| f_{kj} - f_{kh} \right|}{2(n-1)^2 \sum_{\substack{j=1 \\ j\neq k}}^{n} f_{kj} / (n-1)} = \frac{\sum_{\substack{j=1 \\ j\neq k}}^{n}\sum_{\substack{h=1 \\ h\neq k}}^{n}\left| f_{kj} - f_{kh} \right|}{2(n-1)O_k} \\
{}^{I}G_{\bullet k}(m) &= \frac{\sum_{\substack{i=1 \\ i\neq k}}^{n}\sum_{\substack{g=1 \\ g\neq k}}^{n}\left| f_{ik} - f_{gk} \right|}{2(n-1)^2 \sum_{\substack{i=1 \\ i\neq k}}^{n} f_{ik} / (n-1)} = \frac{\sum_{\substack{i=1 \\ i\neq k}}^{n}\sum_{\substack{g=1 \\ g\neq k}}^{n}\left| f_{ik} - f_{gk} \right|}{2(n-1)I_k}
\end{aligned}
\tag{6}
$$

where

$$O_k = \sum_{\substack{j=1 \\ j\neq k}}^{n} f_{kj} : \text{ total outflows from the origin state } k$$

$$I_k = \sum_{\substack{i=1 \\ i\neq k}}^{n} f_{ik} : \text{ total inflows to the destination state } k$$

These outflow and inflow field Gini indices also vary between 0 and 1. This study considers the *z*-scores[7] for each field Gini index for a clearer comparison. Table 2-7 summarizes the actual formulas applied to compute the Gini indices from the 48 by 48 interstate trade matrices for each commodity group (*m*) at time *t* in the section 3.

[7] Z-scores can be calculated by subtracting the averages across all states in the interstate trade system and dividing by their standard deviation. The scores are computed using an SPSS software (SPSS Statistics version 17.0).

Table 2-7. Calculation equations of Gini indices for the U.S. interstate CFS data (1993, 1997, 2002 and 2007)

Gini Index	Equation	Gini Index	Equation
Total Flows	$^{T}G^{m,t} = \dfrac{\sum_{i=1}^{48}\sum_{\substack{j=1 \\ j\neq i}}^{48}\sum_{g=1}^{48}\sum_{\substack{h=1 \\ h\neq g}}^{48} \left\| f_{ij}^{m,t} - f_{gh}^{m,t} \right\|}{2\left[48(48-1)\right]T^{m,t}}$	Outflow Field	$^{O}G_{k\bullet}^{m,t} = \dfrac{\sum_{\substack{j=1 \\ j\neq k}}^{48}\sum_{\substack{h=1 \\ h\neq k}}^{48} \left\| f_{kj}^{m,t} - f_{kh}^{m,t} \right\|}{2(48-1)O_{k}^{m,t}}$
Outflows	$^{T}G_{R\bullet}^{m,t} = \dfrac{\sum_{i=1}^{48}\sum_{\substack{j=1 \\ j\neq i}}^{48}\sum_{\substack{h=1 \\ h\neq i,j}}^{48} \left\| f_{ij}^{m,t} - f_{ih}^{m,t} \right\|}{2\left[48(48-1)\right]T^{m,t}}$	Inflow Field	$^{I}G_{\bullet k}^{m,t} = \dfrac{\sum_{\substack{i=1 \\ i\neq k}}^{48}\sum_{\substack{g=1 \\ g\neq k}}^{48} \left\| f_{ik}^{m,t} - f_{gk}^{m,t} \right\|}{2(48-1)I_{k}^{m,t}}$
Inflows	$^{T}G_{\bullet C}^{m,t} = \dfrac{\sum_{j=1}^{48}\sum_{\substack{i=1 \\ i\neq j}}^{48}\sum_{\substack{g=1 \\ g\neq j,i}}^{48} \left\| f_{ij}^{m,t} - f_{gj}^{m,t} \right\|}{2\left[48(48-1)\right]T^{m,t}}$	$f_{ij}^{m,t}$: commodity flows from state i to j for commodity m at time t $T^{m,t} = \sum_{i=1}^{48}\sum_{\substack{j=1 \\ j\neq i}}^{48} f_{ij}^{m,t}$: total gross flows from i to j for commodity m at time t $O_{k}^{m,t} = \sum_{\substack{j=1 \\ j\neq k}}^{48} f_{kj}^{m,t}$: total outflows from origin k for commodity m at time t $I_{k}^{m,t} = \sum_{\substack{i=1 \\ i\neq k}}^{48} f_{ik}^{m,t}$: total inflows to destination k for commodity m at time t	
Exchanges	$^{T}G_{RC,CR}^{m,t}(m) = \dfrac{\sum_{i=1}^{48}\sum_{\substack{j=1 \\ j\neq i}}^{48} \left\| f_{ij}^{m,t} - f_{ji}^{m,t} \right\|}{2\left[48(48-1)\right]T^{m,t}}$		

2.2.2. Flow matrix factor analysis: Identification of trade regions of interstate trade

Factor analysis has been utilized as one method to abstract an underlying structure of flows from such a large and complex origin-to-destination interaction matrix by reducing sets of flows into basic flow components. This study employs a principal component analysis (PCA) procedure as an extraction method for flow matrix factor analysis.

2.2.2.1. Flow matrix factor analysis

The basic purpose of flow matrix factor analysis is the derivation of clusters of areas with a similar spatial structure of interstate trade flows in terms of the geographic origins and destinations of the flows. In a sense, trading areas (or trading zones) are identified and categorized based on relative similarity of their flows displaying a particular combination of source or destination locations of commodity flows among states.

In undertaking a PCA with commodity flow data, two matrices are examined closely: the origin-to-destination commodity flow matrix and the connection matrix. According to Berry

(1966), the *R*-mode and the *Q*-mode factor analyses need to be carried out for columns and rows of the original flow matrix separately to identify the factors (or components) explaining the spatial structure of commodity flows. It is because the origin-to-destination flow matrices are square, but usually not symmetric. Therefore, a separate analysis should be conducted for columns and rows and different factors are likely to be obtained. The first step of the factor analysis of commodity flow matrix is to compute the correlations between patterns of individual state's inflows (*R*-mode) or outflows (*Q*-mode). For the *R*-mode PCA, a set of 48 by 48 matrices of correlation coefficients between 48 columns representing 48 origin states is produced, while the *Q*-mode PCA requires a set of 48 by 48 matrices of correlation coefficients between 48 rows indicating destination states. These correlation matrices are considered as connection matrices required for flow matrix factor analysis. Two states whose rows have a correlation coefficient of 1 are believed to have *proportionally* identical amount of outflows to every other state. When the coefficient for two states is less than 1, it indicates the extent to which the destinations of two state's outflows differ. A parallel explanation can be made for the correlation between two state's inflows. In other words, two states of which columns have a correlation coefficient of 1 are considered to have *proportionally* equal amount of inflows from every other state. The coefficient for two states less than 1 implies the extent to which the origins of inflows shipped into the two states from are not identical.

The next step is to extract principal components for grouping states with similar commodity flow patterns based on the correlation matrices produced in the first step. The *Q*-mode PCA extracts a set of components based on the similarities in the way origins ship their products to destination so as to yield groups of origin or producing regions, while the *R*-mode PCA accomplishes something of a similar nature based on the similarities in the way destinations assemble their needs so as to identify the selection of destination states. States with high component loadings indicate that they are sharing *proportionally* similar destinations in the former analysis. In the latter analysis, states with high component loadings are interpreted that they have *proportionally* similar origins in common for their inflows. To simplify the structure of component loadings, a rotation technique is often used. In conjunction with loadings on components, the standardized component scores (usually called 'factor scores') on the components for the each state's outflow and inflow assist in understanding the characteristics of the commodity flows. They measure the significance of a destination or an origin for the group of states that have similar outflow or inflow patterns, respectively. When looking into the outflow shipments, a large positive score indicates an especially strong destination of the outflows for those states that load highly on the component. A large negative score, conversely, indicates an extremely weak destination for the outflows from these states that have high component loadings. The interpretation for the inflow shipments can be made in a similar manner. For the states that have high loadings on the component, a large positive score indicates a particularly strong source of inflows, whereas a large negative score represents an extremely weak origin for the inflow shipment into these states.

This study conducts the factor analysis on state-to-state commodity flow matrices over the periods 1993, 1997, 2002, and 2007 using the software of SPSS Statistics version 17.0. Commodity flow matrix factor analyses are executed with the aggregated shipments of all the commodities in terms of value of shipments. In using flow matrix factor analysis using the SPSS software, PCA is employed as an extraction method and correlation matrix of variables is chosen as an analysis object. Those correlation matrices, that denote the connection matrix, are produced by a pair-wise deletion, so that states are compared only for the 46 states (as origins or destinations) that they have in common. Extractions are based on the standard that the eigenvalues are greater than 1.4[8] and a varimax criterion is employed as a rotation technique. And, a regression-based method is employed for calculating the standardized scores of components. All these factor analysis procedures are conducted with an original format of 48 by 48 commodity flow matrix for *R*-mode PCA as well as its transposed matrix for the *Q*-mode PCA, respectively. The former extracts components on inflows to each state and the latter identifies components on outflows from each state. Through these flow matrix factor analyses, the structure of commodity flows in the U.S. will be portrayed in an expression of "trade regions (or trade zones)" based on the spatially similar trading patterns in terms of sharing origins and destinations in an interstate trade system.

2.2.2.2. Dyadic factor analysis of commodity flow patterns

A dyadic factor analysis approach applied by Berry (1966) is replicated to analyze the flow structure of 13 different commodity groups. If the factor analysis procedure mentioned above is applied to all 13 different commodity groups for each year in two different terms of values and weight of shipments, at least 104-time factor analysis (13 commodity groups × 4 years × 2 terms) would need to be conducted. Instead, a dyadic factor analysis is conducted to reduce this large number of steps with state-to-state flow matrices for each specific commodity, and this dyadic factor analysis identifies the general flow pattern that can be understood based on the commodity characteristics. First, the 2,256 (=48×(48-1)) dyads, after excluding the main diagonal dyads,

[8] The cut-off point of eigenvalue that was commonly used in the previous research is 1.0 (Berry, 1966; Black, 1973; Plane & Isserman, 1983; Ellis et al., 1993; Pandit, 1994). However, this study uses 1.4 as the cut-off eigenvalue level for extraction of components. This level was determined by looking into the scree plots. On average, an elbow appears around at the level of eigenvalues between 1.4 and 1.5. Around this level, the number of components extracted (ultimately the number of trade regions grouped based on the factor analysis results) lands between seven and nine, which is almost half as many as the case using the level of eigenvalue greater than 1.0.

are arrayed as row observations with the 13 different commodities by column. The commodity groups are treated as variables in this case. Then, we have eight (for 2 terms × 4 years) dyadic data matrices with 2,256 rows and 13 columns. Given these data matrices, the correlations between the columns are found in the second step. These correlations indicate similarities between the way commodities flow over the dyads of the systems. Finally, a factor analysis of these correlations groups commodities on the factor (or component). All detailed methods employed for this factor analysis are the same as those applied to the factor analysis described in the previous section except the cut-off point of eigenvalue is for a level greater than 1.0. Component scores are also calculated for each dyad on each component. Through this dyadic factor analysis on commodity groups as well as subsequent mapping processes with results, the major commodity flow patterns in the U.S. during 1993~2007 will be portrayed.

3. Analysis results: Spatial patterns of U.S. interstate commodity flows

3.1. "Spatial focusing" in interstate trade system

First, four components of Gini index for the total flows of U.S. interstate trade for 1993, 1997, 2002, and 2007 are calculated and summarized in the raw coefficients as well as the standardized values as shown in Table 2-2.

The values of the overall total flows Gini index for all the four years are greater than 0.7 in terms of the value of shipments and 0.8 in terms of tons shipped. Although overall fluctuations have been observed, a relatively slight decrease in 2007 is noticed compared to the overall total flow Gini index of 1993, which would suggest the overall extent of trade system is becoming a little less spatially focused. In a comparison of total flows index values between the value and weight of shipments, those for tons appear to be greater indicating that they are more spatially focused. It might imply tons of commodities shipped might be influenced by distance factors, so that the movement appears more spatially focused, or more localized. However, *spatially focused* based on Gini index value does not necessarily mean the pairs of state trading are located close each other in terms of distance. With the exception of 2002, the column Gini index values for the origin selections of inflows are higher than the row Gini index values for the destination selections of outflows. However, the differences between the row and column indices are quite small.

Table 2-8. Total flows Gini index values for the U.S. interstate trade for 1993, 1997, 2002, and 2007

In terms of Value	1993		1997		2002		2007	
Component	Index	%	Index	%	index	%	index	%
Rows (Outflows)	0.012638	1.724%	0.012393	1.714%	0.012758	1.737%	0.012384	1.703%
Columns (Inflows)	0.012721	1.735%	0.012438	1.721%	0.012735	1.733%	0.012842	1.766%
Exchanges	0.000089	0.012%	0.000087	0.012%	0.000102	0.014%	0.000091	0.012%
Other Flows*	0.707601	96.529%	0.697942	96.553%	0.709061	96.516%	0.701919	96.519%
Overall Total Flows	0.733049		0.722860		0.734656		0.727236	

In terms of Ton	1993		1997		2002		2007	
Component	Index	%	Index	%	index	%	index	%
Rows (Outflows)	0.015581	1.890%	0.015518	1.886%	0.015680	1.892%	0.015428	1.875%
Columns (Inflows)	0.015640	1.897%	0.015545	1.889%	0.015562	1.878%	0.015629	1.900%
Exchanges	0.000178	0.022%	0.000186	0.023%	0.000187	0.023%	0.000186	0.023%
Other Flows*	0.793002	96.191%	0.791456	96.202%	0.797228	96.207%	0.791438	96.202%
Overall Total Flows	0.824401		0.822705		0.828657		0.822682	

* Other Flows includes all other nontrivial flows except outflows, inflows and bilateral exchange flows. Since the number of pairs is relatively large, their indices are marked as high values.
Note: Calculated by author
Data source: CFS 1993, 1997, 2002, and 2007

Table 2-9 summarizes the results based on the CFS movements of all the comprehensive commodities; it would be expected that the general interstate trade flow would tend to show similar counter-stream in two opposite flow directions of outflow and inflow. In a word, the flows in both directions between large states generally will be larger than those between smaller states, and this structural property would result in fairly similar row and column indices. When looking into these index values for mining and manufacturing commodities shipped separately, mining products shipped appear to have a more spatially focused movement over the interstate trade system compared to other manufactured goods. As for the row and column Gini indices, the mining products tend to have higher column Gini index values for all four years whereas manufactured goods are no different from the general trends of all the aggregated commodities shipped. These differences stem from the fact that mining products, as natural resources, are much more dependent on specific sources.

Table 2-9. Total flows Gini index values for the values of shipment in 1993, 1997, 2002 and 2007

		1993		1997		2002		2007	
Sector	Components	index	%	Index	%	index	%	index	%
Mining	Overall Total Flows	0.96829		0.95896		0.97451		0.95353	
	Rows (Outflows)	0.01831	1.89%	0.01793	1.87%	0.01834	1.89%	0.01822	1.91%
	Columns (Inflows)	0.01949	2.01%	0.01909	1.99%	0.01955	2.01%	0.01904	2.00%
	Exchanges	0.00040	0.04%	0.00038	0.04%	0.00042	0.04%	0.00038	0.04%
	Other Flows*	0.93010	96.05%	0.92157	96.10%	0.93620	96.07%	0.91589	96.05%
Manufacturing	Overall Total Flows	0.77213		0.78054		0.80476		0.77950	
	Rows (Outflows)	0.01333	1.73%	0.01342	1.72%	0.01428	1.77%	0.01335	1.71%
	Columns (Inflows)	0.01346	1.74%	0.01342	1.72%	0.01369	1.70%	0.01362	1.75%
	Exchanges	0.00009	0.01%	0.00009	0.01%	0.00012	0.02%	0.00009	0.01%
	Other Flows*	0.74525	96.52%	0.75360	96.55%	0.77668	96.51%	0.75242	96.53%
(1) Nondurable	Overall Total Flows	0.78375		0.79378		0.82275		0.79553	
	Rows (Outflows)	0.01386	1.77%	0.01395	1.76%	0.01493	1.82%	0.01406	1.77%
	Columns (Inflows)	0.01393	1.78%	0.01386	1.75%	0.01438	1.75%	0.01411	1.77%
	Exchanges	0.00011	0.01%	0.00009	0.01%	0.00014	0.02%	0.00012	0.02%
	Other Flows*	0.75585	96.44%	0.76588	96.49%	0.79330	96.42%	0.76724	96.44%
(2) Durable	Overall Total Flows	0.78363		0.79069		0.81704		0.78828	
	Rows (Outflows)	0.01318	1.68%	0.01337	1.69%	0.01425	1.74%	0.01316	1.67%
	Columns (Inflows)	0.01368	1.75%	0.01370	1.73%	0.01402	1.72%	0.01387	1.76%
	Exchanges	0.00011	0.02%	0.00012	0.02%	0.00014	0.02%	0.00012	0.02%
	Other Flows*	0.75666	96.56%	0.76350	96.56%	0.78864	96.52%	0.76113	96.56%

* Other Flows includes all other nontrivial flows except outflows, inflows and bilateral exchange flows. Since the number of pairs is relatively large, their indices are marked as high values.
Note: Calculated by author
Data source: CFS 1993, 1997, 2002, and 2007

Table 2-10. Total flows Gini index values for the tons shipped in 1993, 1997, 2002 and 2007

		1993		1997		2002		2007	
Sector	Components	Index	%	index	%	index	%	Index	%
Mining	Overall Total Flows	0.97499		0.97400		0.97962		0.97312	
	Rows (Outflows)	0.01781	1.83%	0.01814	1.86%	0.01803	1.84%	0.01754	1.80%
	Columns (Inflows)	0.01969	2.02%	0.01968	2.02%	0.01983	2.02%	0.01978	2.03%
	Exchanges	0.00040	0.04%	0.00040	0.04%	0.00042	0.04%	0.00040	0.04%
	Other Flows*	0.93709	96.11%	0.93578	96.08%	0.94134	96.09%	0.93539	96.12%
Manufacturing	Overall Total Flows	0.81932		0.82702		0.85068		0.82251	
	Rows (Outflows)	0.01530	1.87%	0.01526	1.85%	0.01604	1.89%	0.01530	1.86%
	Columns (Inflows)	0.01527	1.86%	0.01523	1.84%	0.01572	1.85%	0.01521	1.85%
	Exchanges	0.00012	0.02%	0.00012	0.01%	0.00016	0.02%	0.00012	0.02%
	Other Flows*	0.78862	96.25%	0.79642	96.30%	0.81876	96.25%	0.79188	96.28%
(1) Nondurable	Overall Total Flows	0.82824		0.84151		0.86519		0.83274	
	Rows (Outflows)	0.01545	1.87%	0.01564	1.86%	0.01633	1.89%	0.01552	1.86%
	Columns (Inflows)	0.01554	1.88%	0.01564	1.86%	0.01621	1.87%	0.01546	1.86%
	Exchanges	0.00014	0.02%	0.00014	0.02%	0.00019	0.02%	0.00015	0.02%
	Other Flows*	0.79710	96.24%	0.81009	96.27%	0.83246	96.22%	0.80161	96.26%
(2) Durable	Overall Total Flows	0.83984		0.83757		0.86877		0.84064	
	Rows (Outflows)	0.01540	1.83%	0.01505	1.80%	0.01614	1.86%	0.01533	1.82%
	Columns (Inflows)	0.01575	1.88%	0.01551	1.85%	0.01613	1.86%	0.01576	1.88%
	Exchanges	0.00015	0.02%	0.00016	0.02%	0.00019	0.02%	0.00014	0.02%
	Other Flows*	0.80854	96.27%	0.80685	96.33%	0.83632	96.27%	0.80940	96.28%

* Other Flows includes all other nontrivial flows except outflows, inflows and bilateral exchange flows. Since the number of pairs is relatively large, their indices are marked as high values.
Note: Calculated by author
Data source: CFS 1993, 1997, 2002, and 2007

Next, the outflow and inflow field Gini indices for each state are computed and their standardized index values in a form of *z*-score are plotted in Figure 2-1. A positive *z*-score means that a state's trade field is more spatially focused than average, indicating its strong role in the interstate trade system. Negative *z*-scores indicate that a state's field is broader, or less focused. Negative *z*-scores for inflows indicate that commodities are shipped from diverse origin states, whereas negative *z*-scores for the outflow field Gini index suggest that commodities are shipped to widely dispersed destinations. When a 45° line is drawn on the scatter plots in Figure 2-1, the relative magnitudes of the standardized outflow and inflow field indices can be compared easily. States with larger *z*-score of inflow field index than that of outflow are plotted above the 45° line. The corresponding state is one where outflow is relatively uniform across all destinations, whereas inflow is more highly focused and comes from selective origins. States plotted below the 45° line represent to have a larger outflow field index values than inflow field index values. The state that falls into the latter category is one where inflow is relatively uniform across all origins while outflow goes to selective destinations wherever they might be. In particular, states with index values greater than one standard deviation above or below the mean would be of special interest when examining the scatter plots shown Figures 2-1.

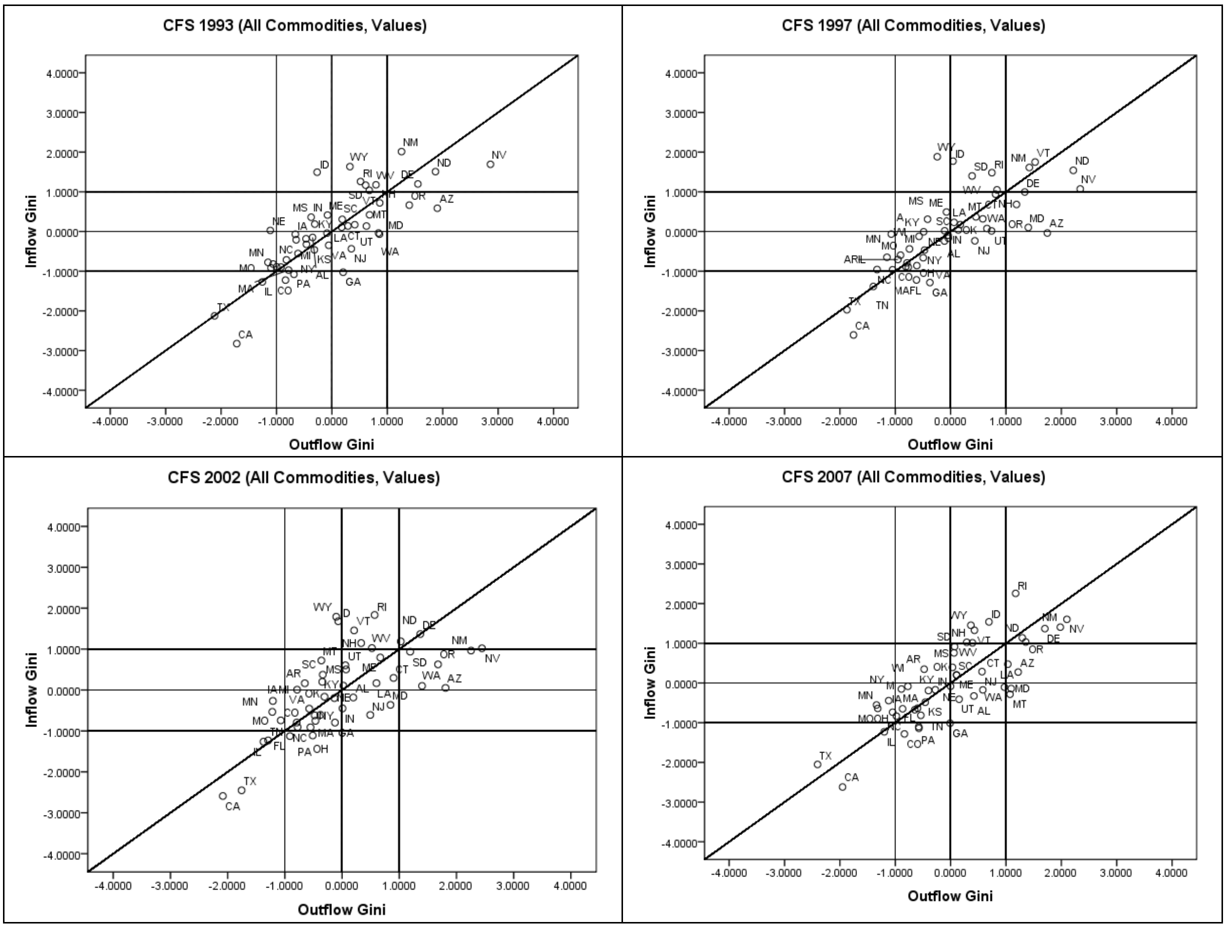

Figure 2-1. Scatter plots of field Gini index values for U.S. interstate commodity flows, 1993~2007

Note: calculated in the basis of the value of shipment for all commodities

Data source: CFS 1993, 1997, 2002, and 2007

The state with a z-score of the row field index value greater than 1 implies that the state has spatially focused destinations for its outflows whereas the state whose the z-score of the column field index greater than 1 means that the source states of its inflows are spatially focused. The state that has the z-score of each field indices' values of less than -1 represents to have distinctively broad or spatially extensive trade fields with substantially below-average spatial focusing. The former cases are defined as "states with focused trade fields" while the latter ones are as "states with broad trade fields". Table 2-11 summarizes the typology of spatial focusing of interstate outflows and inflows fields in the interstate trade system for all the aggregate commodities across the four time periods.

First, there is no state that has a focused trade field of origins but a broad trade field of destinations, or vice versa. Secondly, no state switches between the list of focused fields and the list of broad fields. Thirdly, the high positive correlation between the outflow and inflow trade field measures is confirmed. In most cases, outflow and inflow fields for particular states are similar, and the corresponding states are indicated in a bold letter in Table 2-11 and displayed on the maps in Figure 2-2.

Table 2-11. Typology of focusing of interstate in- and out-flow fields for 1993, 1997, 2002, and 2007

Year	1993	1997	2002	2007	1993	1997	2002	2007
	Destinations				Origins			
States with focused trade fields of	**NV**	**NV**	**NV**	**NV**	**NM**	WY	RI	**RI**
	AZ	**ND**	NM	**NM**	**NV**	ID	WY	**NV**
	ND	AZ	AZ	**DE**	WY	**VT**	ID	ID
	DE	**VT**	OR	**OR**	**ND**	**NM**	VT	WY
	OR	**NM**	WA	**ND**	ID	**ND**	**DE**	**NM**
	NM	MD	**DE**	AZ	RI	RI	**ND**	**DE**
	(6)	DE	SD	**RI**	**DE**	SD	NH	VT
		OR	**ND**	MD	WV	**NV**	WV	**ND**
		(8)	(8)	MT	SD	WV	**NV**	**OR**
				LA	VT	(9)	(9)	NH
				(10)	(10)			WV
								(11)
States with broad trade fields of	**TX**	**TX**	**CA**	**TX**	**CA**	**CA**	**CA**	**CA**
	CA	**CA**	**TX**	**CA**	**TX**	**TX**	**TX**	**TX**
	IL	**TN**	**IL**	MN	**IL**	**TN**	**IL**	CO
	MN	IL	**TN**	MD	CO	GA	**TN**	**IL**
	NE	MN	MN	**IL**	PA	FL	FL	PA
	MO	IA	IA	NY	GA	(5)	(5)	TN
	OH	NC	MO	OH	(6)			GA
	(7)	(7)	(7)	(7)				(7)

Note: States listed in each grouping are ranked in descending order of the size of the larger of their two Gini indices
Data source: CFS 1993, 1997, 2002, and 2007 (based on the values of shipment)

Figure 2-2. States with highly focused or especially broad interstate trade fields, 1993-1997-2002-2007
Data source: CFS 1993, 1997, 2002, and 2007 (all commodities, value)

When looking into the spatially focused trade fields, there might be three potential clusters: one each in the West, Central and East. As for the spatially broad trade fields, California, Texas, and Illinois or Tennessee are detected as dominant node states for both their outflows and inflows. These states interact with others in context of the total U.S. trade system compared to the states that have focused trade fields. In particular, California is identified as the strongest trade consuming state that attracts outflows from various states over the four time periods. At the same time, California has a dominant role in distributing commodities to other states over the entire U.S. during all four periods. As a distributor to other states, Texas is identified are a state that is more significant compared to California except in 2002. The Gini field indices are useful measures to examine system-wide properties of the interstate commodity flows and simply compare the degree to which the sources of inflows versus the destinations of outflows for each state are spatially focused. However, they neither identify the location of the dominant source/origin or market/destination nor sort out effects that make trade system a spatially focused phenomenon. For example, Nevada is detected to have the highest level in terms of a focused trade field for its outflows. However, it is not possible to know exactly where the major destinations trading with Nevada are located and why it has such a focused outflow trade field. Hence, in the next section the focus will be oriented more on identifying the trading partners of each state in the whole U.S. interstate trade system.

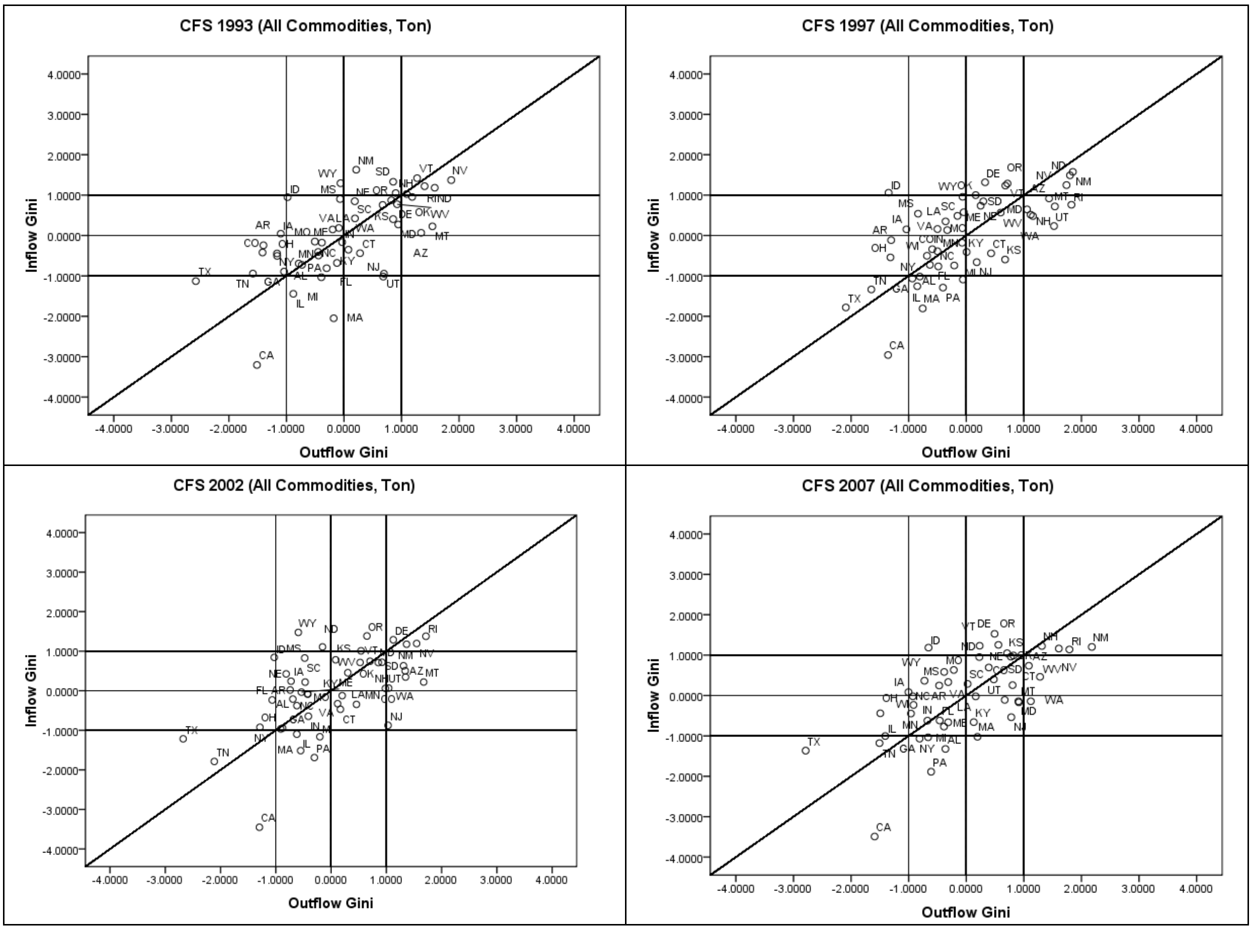

Figure 2-3. Scatter plots of field Gini index values for U.S. interstate commodity flows, 1993~2007

Note: calculated in the basis of the tonnage of shipment for all commodities

Data source: CFS 1993, 1997, 2002, and 2007

Figure 2-4. States with highly focused or especially broad interstate trade fields, 1993-1997-2002-2007
Data source: CFS 1993, 1997, 2002, and 2007 (all commodities, ton)

Before moving to the next section, a few other comments are necessary. First, Illinois has played a significant role as a major trade distributor for both outflows and inflows in the U.S. interstate trade system even though its Gini field index values fluctuate over the four time periods. Secondly, Tennessee has been another emerging important trade distributor. Finally, the pattern of spatial focusing of interstate trade fields based on the tonnage of shipment appears very similar to the pattern based on the value of shipment over the four time periods.

3.2. Identification of U.S. interstate trade regions

The Gini index was utilized to simply examine the degree of spatial focusing found in an interstate trade system in the previous section. This section places more attention on the spatial extent of shipments of commodities based on the similarity of spatial structure of their trade flows so as to group into a typology of regional trade regions the entire Unites States.

3.2.1. Regional stability of commodity flow patterns

This section interprets and summarizes the results obtained from the commodity flow matrix factor analysis based on the PCA as described above. The PCA procedures produce trade regions as typologies by identifying clusters of areas with a similar spatial structure of commodity trade flow as given by the geographic origin of their inflows or the geographic destination of their outflows. Essentially, the crucial criterion for regional grouping is the relative similarity of their flows with other trading states. Hence, the trade regions here can be defined as typologies, each representing a particular combination of source or destination states in the whole interstate trade system. The states categorized as one trade region based on commodity inflows represent consuming (or importing) regions while the states grouped as one trade region based on commodity outflows stand for producing (or exporting) regions.

The results of flow matrix factor analysis show four remarkable features of interstate trade patterns. First of all, the regional groupings of states having similar trade outflow patterns, and those having similar inflow patterns are not similar. The areas of a trade-producing region are on average larger then those of a trade-consuming region. The number of regional groupings based on inflow movements is a little larger than that of regional groupings based on outflow movements. It might imply the geographical patterns of inflows are more spatially concentrated, which is consistent with the results based on Gini indices in the previous section. When comparing the rows and columns indices, the column Gini index values showing the spatial focusing of inflows are larger than row Gini index values measured based on outflows.

Secondly, a tight geographic pattern of commodity flows is noted for each year. This means that members in a trading zone (or region) are geographically adjacent states based on either common destinations or origins for their commodity flows. Thirdly, greater stability is observed when examining into the trend for the overall patterns of trade-producing regions notwithstanding some local variations across the four time periods. From 1997, the trade outflow system with seven trade regions seems to have been established even though a couple of disturbances are observed. In 1993, all 47 U.S. states are grouped into eight trade producing regions: West, South Central, Middle Central, East North Central, West North Central, South Atlantic, Middle Atlantic and New England. In 1997, New England and Middle Atlantic regions appear to have three trade producing sub-regions. However, a more remarkable finding is that states in the Middle Central region start to be included into either the West North Central or South Central regions. In particular, a seven-region structure based on the trade outflows has been in place since 2002 although a couple of shifts are observed in Illinois and Mississippi between 2002 and 2007.

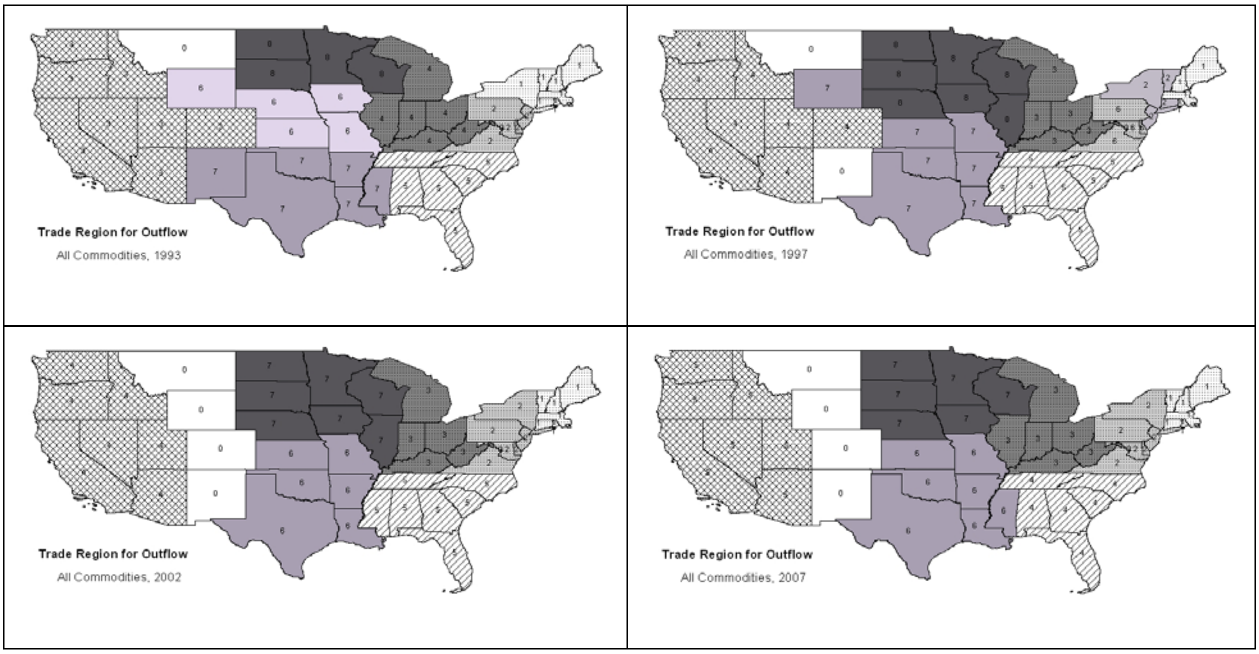

Figure 2-5. Trade producing regions based on the outflows in the United States in 1993, 1997, 2002, and 2007

Note: Each number found in a group (with the same shading) indicates that the corresponding states are categorized into the same trade region.

Data source: CFS 1993, 1997, 2002, and 2007 (all commodities, value)

Finally, a more fluctuating trend over time is observed in the overall patterns of trade-consuming regions. Even though there is a variation in Virginia from 1993 to the later years, the trade consuming regions in the East coast are strongly stable across four different time periods. For the western part of the US, two major trade consuming regions, North West trade consuming region that covers Washington, Oregon and Idaho and the South West trade consuming region that includes California, Nevada, Arizona, Utah, Colorado and Kansas, are identified. However, this general pattern shows remarkable changes in 1997 and 2007, respectively. The South West trade consuming region is extended to embrace Texas and Montana in 1997. In 2007, the two trade-consuming regions of North West and South West are amalgamated into one big West trade-consuming region. Along with these shifts in the western area, some turbulence is also observed in the Mountain region including Montana, Wyoming and New Mexico over the time periods. In particular, Texas makes several shifts in affiliation across the four time periods. Texas is one major member of the trade consuming region in the South Central area in 1993, 2002 and 2007. However, it is found as one constituent of the South West trade consuming region that encompasses California, Arizona, Nevada, Utah, Colorado, New Mexico and Montana instead of the usual South Central trade consuming region in 1997. With this variation of Texas, the Central trade consuming regions are newly arranged and defined in 1997 as well. For the central area, only two trade consuming regions can be defined: South Central and West North Central regions. Along with this turbulence in the Central regions, the changes in the spatial roles or effects of Illinois and Iowa as trade consuming states are also notable. However, all these detected shifts are interpreted in relative terms to the stability of trade producing regions. Although the trade-consuming regions seem to have more dynamically variegated geographical arrangements compared to the geographical association patterns that the trade producing regions revels since 1993, we still can conclude that trade-consuming regions also show the regional stability for the period of analysis. They remain a stable range of number of regional grouping between eight and nine over the study years.

The maps visualizing each trade region with states either having common dominant destination states or having common dominant origin states in figure 2-5 and 2-6 do not provide the detailed information on where the destinations or origins are. Based on the standardized component scores, the dominant destinations of outflows (based on *Q*-mode PCA) and the dominant origins of inflows (based on *R*-mode PCA) for each trade producing region and trade consuming region are detected and presented on the checkerboards in the Table 2-12 and Table 2-13, respectively. The destinations or the origins that have the component scores greater than 1.0 are considered dominant ones in this study.

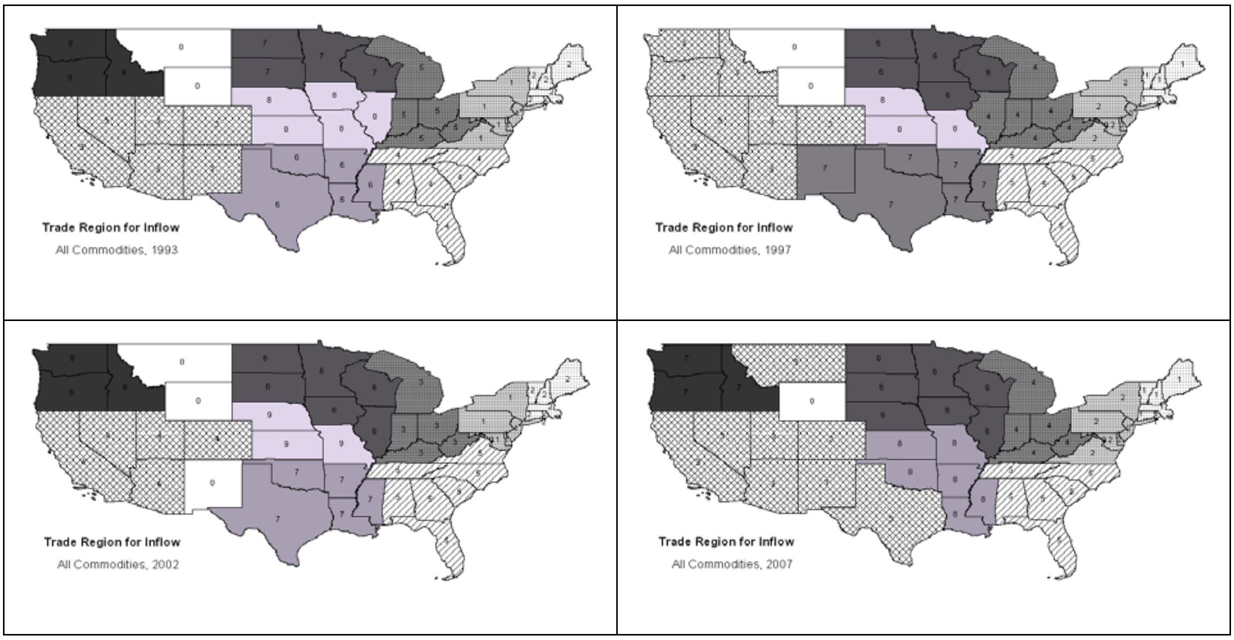

Figure 2-6. Trade consuming regions based on the inflows in the United States in 1993, 1997, 2002, and 2007

Note: Each number found in a group (with the same shading) indicates that the corresponding states are categorized into the same trade region.

Data source: CFS 1993, 1997, 2002, and 2007 (all commodities, value)

When looking into the dominant destination states for the corresponding trade producing regions, the pairs of origin-destination state are roughly consistent (Table 2-12). As for the selection of origins of trading consuming regions, the pairs of destination-origin states seem a little bit more variable (Table 2-13). However, they are not really dramatically different from each other. A cell which is lightly shaded and contains an asterisk in tables indicates that the state is one of the members comprising the corresponding trade region at the same time as it is one of the dominant destination (or origin) states which imports (or exports) more commodities from (or to) the trade region compared to others. Overall, the trade system based on the spatial structure of outflows show a more stable structure by region and over time. In particular, the correspondence between origins and destination is prominent in 2007. If a cell is found shaded but not to have an asterisk, the corresponding state is a weak destination (or origin) for the corresponding trade producing region (or trade consuming region). More attention should be directed to the cell that has an asterisk but not shaded since the cell represents one of the very influential destinations (or origins) in the whole U.S. interstate trade system. For the outflows, California, Texas, Illinois, New York, Virginia, Tennessee, Alabama, Iowa and West Virginia are detected as such influential destinations. Here, several features should be noted. First, California, Texas, Illinois and New York play a significant role as one of the dominant destinations in the West, South, Central and East, respectively. Secondly, Midwestern states such as Illinois and Iowa or southeastern states such as Alabama, Tennessee and West Virginia might have a more significant influence on the local outflow trade system in the Midwest and South areas, respectively. Thirdly, most states with the exception of California are usually importing more from the close states based on their geographic contiguity; California acts as a dominant destination for its close states as well as for distant states across all the four time periods.

This finding is consistent with the negative trade Gini field index for outflows from California. Comparable patterns are detected in Table 2-13 presenting the selection of dominant origin states of inflows moving into the trade consuming regions. A more varied trend in the selections of origins over time is observed for inflows compared to the selections of destinations for outflows. However, these variations might be negligible in contributing to the total understanding the overall U.S. interstate trade system. For both cases, the observed fluctuations are smoothed out if a broader range of geographical configurations is considered. The boundaries of the regional groups in both cases above can be compared to the boundaries of eight economic regions designated by the U.S. Bureau of Economic Analysis (BEA) based on economic similarities among contiguous states. They are roughly similar, especially in the eastern U.S. areas. For the central U.S. areas, the Plains economic regions are easily divided into two in terms of trade regional system. According to the BEA economic regional grouping, Arkansas and Louisiana are in the South East regions with other south eastern U.S. states. However, according to the trade regional grouping chosen in this study, they are encompassed into the trade regions usually defined by including Texas and its adjacent states in the south central area. As for the western area, a different pattern of regional grouping is observed. However, it is expected that the boundaries produced by two different regional groupings are not exactly identical since the definition of trade regions here is based only on the spatial structure of outflows or inflows of commodity movement over the U.S. states. In addition and more importantly, it might be attributable to the arbitrariness the method employed in this study for regionalization for each case. For instance, another option for regionalization of interregional trade patterns with different cut-off levels of eigenvalues or component loadings and scores might yield some different details. However, the important thing to remember is that trade is one component of regional economic activities, one product of regional economies as well as one stimulus of regional economies. Hence, the spatial pattern of interstate trade might reflect regional economic structure for each state in a multi-state economic system such as the U.S. It is also shown from the observation that the overall trade regions in the U.S. interstate trade system based on major origin-destination pairs are ultimately mapped into four large regions, West, Midwest, South, and North East, which are consistent with the four U.S. Census regions.

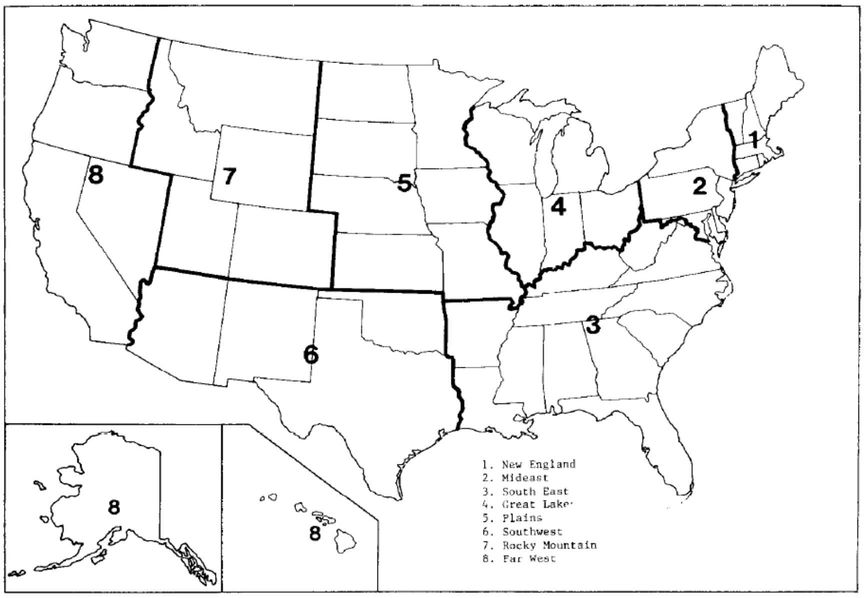

Figure 2-7. The eight BEA Economic Regions of the United States
Source: *Map 10* in the page 262 of the paper by Plane & Isserman (1983)

Table 2-12. Checkerboard identifying the dominant destination states for each trade producing regions, 1993~2007

Q	TR	MA	NY	NH	CT	CA	RI	PA	NJ	MD	VA	UT	WA	NV	OR	AZ	ID	OH	MI	IN	IL	KY	NC	GA	SC	FL	TN	AL	MO	KS	TX	IA	NE	OK	LA	MS	AR	MN	ND	SD	WI	ME	CO	DE	MT	NM	VT	WV	WY
1993	1	*	*	*	*	*	*																																										
	2		*					*	*	*	*																																						
	3					*						*	*	*	*	*	*																																
	4																	*	*	*	*	*																											
	5										*												*	*	*	*	*	*																					
	6																				*								*	*	*	*	*	*															
	7																										*	*			*			*	*	*	*												
	8																															*						*	*	*	*								
1997	1	*				*	*																																			*							
	2		*		*			*	*																																						*		
	3																	*	*	*	*	*																											
	4					*						*	*	*	*	*	*																																
	5																						*	*	*	*	*	*																					
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	7					*																							*	*	*			*	*		*												
	8					*															*											*	*					*	*	*	*								
2002	1	*	*	*	*																																					*							
	2		*					*	*	*	*																																	*					
	3																	*	*	*	*	*					*																						
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	6																				*								*	*	*			*			*												
	7					*															*											*	*					*	*	*	*								
2007	1	*	*	*	*		*																																										
	2		*					*	*	*	*																																	*					
	3																	*	*	*	*	*																										*	
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	7																				*											*	*					*	*	*	*								

Note 1: The author summarized the results of *Q*-mode PCA with the value of shipment for each state's outflow.
Note 2: The cell with an asterisk indicates one of dominant destination states of the corresponding trade producing region (by row). The member states of the trade producing region are identified by shading the cell representing the corresponding state in light gray.
Note 3: the order of columns is determined by following the descending order of the component scores for each trade regions for the year of 1993
Data Source: CFS 1993, 1997, 2002, and 2007

Table 2-13. Checkerboard identifying the dominant origins for each trade producing regions, 1993~2007

R	1993									1997								2002									2007							
TR	1	2	3	4	5	6	7	8	9	1	2	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8
MA		*								*									*								*							
NY	*	*								*	*							*	*								*	*						
NH		*								*									*								*							
CT		*								*									*								*							
CA			*						*			*									*				*				*		*		*	
RI		*																	*								*							
PA	*										*							*										*						
NJ	*										*							*										*						
MD	*										*							*										*						
VA	*										*							*				*						*						
UT			*									*									*												*	
WA									*			*													*								*	
NV												*									*								*					
OR									*			*													*								*	
AZ			*									*									*								*					
ID									*																*								*	
OH					*								*							*										*				
MI					*								*							*										*				
IN					*								*							*										*				
IL					*		*	*					*		*		*			*			*			*				*		*		
KY					*								*							*										*				
NC				*										*								*									*			
GA				*										*								*									*			
SC				*										*								*									*			
FL				*										*																	*			
TN				*		*								*						*		*		*							*			*
AL				*										*								*		*							*			
MO								*									*									*						*		*
KS								*									*									*								*
TX			*			*						*				*								*		*			*					*
IA							*	*							*		*						*			*						*		
NE								*									*									*						*		
OK						*										*								*		*								
LA						*										*								*										*
MS						*										*								*										*
AR						*										*								*										*
MN							*								*								*									*		
ND							*								*								*									*		
SD							*								*								*									*		
WI							*								*								*									*		
ME		*																	*								*							
CO																					*								*					
DE																		*										*						
MT																																		
NM																*													*					
VT																																		
WV					*																									*				
WY																																		

Note 1: The author summarized the results of *R*-mode PCA with the value of shipment for each state's inflow.
Note 2: The cell with an asterisk indicates one of dominant origin states of the corresponding trade consuming region (by column). The member states of the trade consuming region are identified by shading the cell representing the corresponding state in light gray.
Note 3: the order of rows is just following the defined order of columns in Table 2-12
Data Source: CFS 1993, 1997, 2002, and 2007

3.2.2. Spatial patterns of trade flow by commodity

Dyadic factor analysis based on commodity-specific interstate trade flows produces two main outcomes. First, dyadic factor analysis support the results obtained from the previous analyses. Secondly, dyadic factor analysis abstracts the interstate trade flows based on the characteristics of commodities. This section focuses on the second findings, and explores the patterns of interstate commodity flows in 2007 only. This enables us to concentrate more effectively on the comparison by commodity groups. The results from the analyses based on both value of shipment and quantity of shipment are summarized.

In the dyadic factor analysis with the value of shipments in 2007, two main components are extracted. The first component, that accounts for 39.40% of this variance, has high component loadings for flows of major consumption goods such as food and kindred commodities, textile, apparel and leather goods, paper and printing related commodities, chemical products, electronic and electric, and wood and furniture products. The second components explains 23.37% of the variance and loads highly on the flows of production-related goods such as mining products, metallic, machinery, transportation equipment products and all kinds of services including transportation, communication and utilities. In order to depict the pattern of dominant commodity flows over the U.S., flow dyads which have component scores greater than 4.0[9] are distilled and represented on the map in Figure 2-8.

The flows explained by the first component have their main node located in the major U.S. states such as California, Texas, New York, and Illinois. It implies these states are playing a significant role in the economic activities related to consumption goods. The flows explained

[9] This value was arbitrarily selected here. However, this level was decided after several trials with different level of component scores in order to find an appropriate level that shows the pattern more effectively from the perspective of comprehension as well as visualization. Berry (1966) abstracted the dominant flows by applying the cut-off level of component score of 3.0 for 36 geographic units in India. This study needs higher level of score cut-off point since it deals with 48 states yielding total 2256 dyads.

by the second component reveal a more geographically concentrated pattern of interaction in the Midwest region represented by Illinois, Indiana, Michigan, Ohio and Kentucky and in the North East region including New York, New Jersey, Pennsylvania, and West Virginia. Related to the second component here, Texas is distinguished as one of main destinations. It might imply that more production-related economic activities are occurring in those regions.

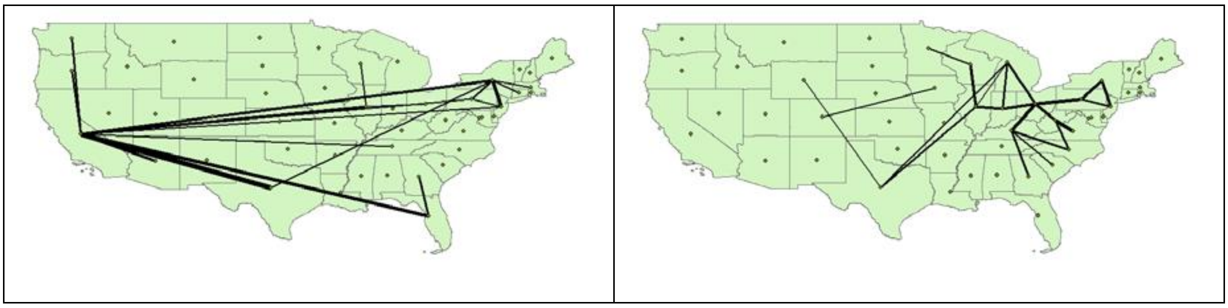

Figure 2-8. Dyad factor analysis: Flow networks explained by component 1 (first map) and 2 (second map)
Data source: 2007 CFS (based on the value of shipments)

The dyadic factor analysis based on the shipment quantity in tonnage in 2007 extracts three main components. The first component has high component loadings mainly for flow dyads of nondurable manufactured goods such as food, beverage, tobacco, textile, apparel, leather, paper and printing related goods and chemical products, and explains 25.63% of the variance. The second component explains 25.35% of the variance which shows almost same level of explanation as the first component does. This second component has high loadings on the flows for the durable manufactured goods such as primary metallic and fabricated metallic products, machinery, electrical and electronic equipments, and transportation equipments. For the first case, trade interactions between states in the South, North East and West regions appear dominant. For the second case, states in the Midwest region play an important role as dominant trading nodes along with some economically important states such as California, Texas, New York and Pennsylvania. In addition to the two components mentioned above, there is the third component that explains 8.63% of the variance and is highly loaded on the flows related to mining sector. The flows explained by this third component have two major exporting nodes - West Virginia and Wyoming. West Virginia feeds the demand in the East coast and Midwest region while Wyoming meets the demand mainly from the West and Midwest regions.

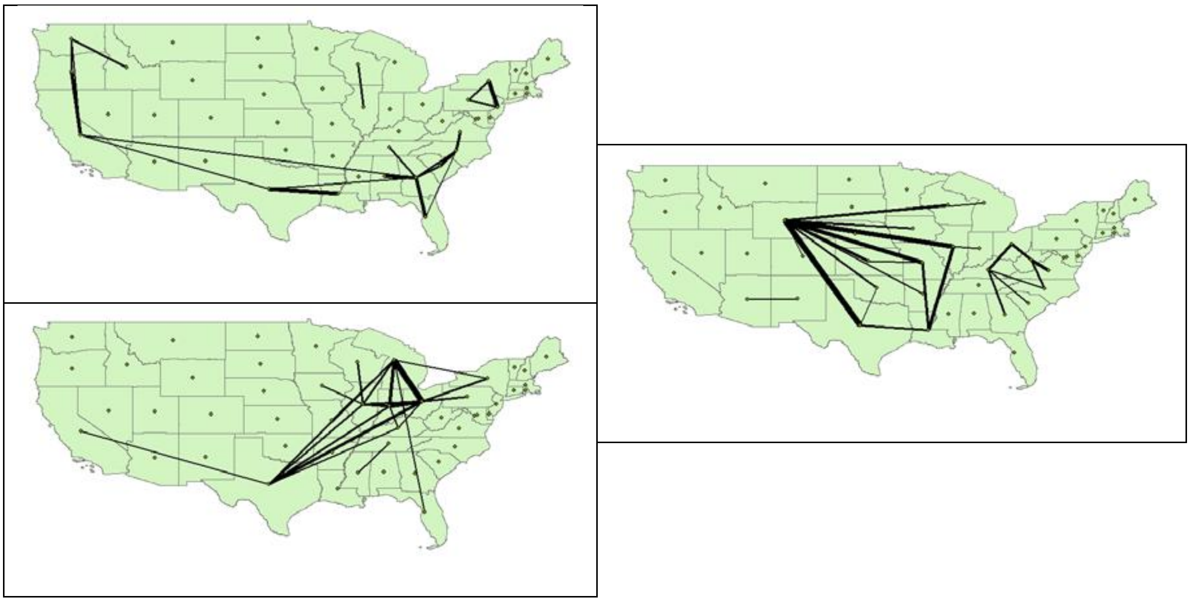

Figure 2-9. Dyad factor analysis: Flow networks explained by component 1 (left above), component 2(right middle) and component 3 (left below)
Data source: 2007 CFS (based on tonnage of shipments)

4. Conclusion

This chapter explores the spatial pattern of U.S. interstate trade among 48 states for four different time periods of 1993, 1997, 2002, and 2007 with the goal of exploring the shifts observed in the U.S. trade system during the last 15 years. Two main methods are employed: trade Gini index measures and flow factor analysis. Using the trade Gini indices, the analysis presents the spatial association in the distribution of interstate trade. In particular, trade field Gini indices help examine whether a state has a spatially focused or a broad trade field in the U.S. interstate commodity flow system. Through two sets of flow factor analyses, the trade regions are defined on the basis of the outflows and inflows of the individual states, respectively, and the trade patterns are extracted reflecting the characteristics of commodity groups.

The main results are summarized as follows. The global spatial pattern or structure of the U.S. interstate commodity flows has been relatively stable during the years of analysis. However, some variations or disturbances at a more detailed or local level are noted although they are quite subtle. Since 1993, the entire interstate commodity flow system seems to have become less spatially focused based on the total trade flows Gini index. In addition to the decreased total flows Gini index, trade regions defined by flow factor analysis display more expanded areas of trading regions with fewer numbers of trade regions over time even though the degrees of changes are relatively small. These findings may imply the changing spatial structure of production derived by hollowing-out effect and fragmentation of production. Each region has experienced the shift in its industrial production structures, so that it has extended or reorganized its trading extent by opening up its new markets or finding it new sources. Provided that more detailed or micro-level of regional (geographical) scale-based trade data was available, more substantive observation could be obtained.

Another finding is that the general spatial pattern of interstate trade still reflects a geographical structure based on contiguity except for the case of California. California is observed as the most significant and influential trading actor in the U.S. interstate trade system across all the years of analysis. Not only the geography but also the influence of increased energy cost might explain the geographical contiguity observed in interregional trade partnership. Another future research opportunity should be made for the role of energy prices in the production fragmentation process and regional trade patterns. Generally speaking, similar and correspondent counter-stream flow patterns exist in the trade flows between origin state and destination states even though the selection of origins of the inflows appears more spatially focused and more variable over time than the selection of destinations of the outflows. However, all these patterns are mainly based on the analyses with the whole aggregate commodity groups. If commodity-specific flows are examined, more diverse and interesting results can be obtained. For instance, mining-related commodities show the most spatially focused trade pattern that is bound to the sources of its resources. On the contrary to the natural resources, manufactured goods reveal a much more spatially dispersed and extensive trading patterns. In fact, dyadic factor analysis reveals that manufactured goods have the more spatially dispersed flow patterns although some differences are detected between consumption and production goods or between nondurable and durable goods.

In conclusion, the regional stability of U.S. interstate trade system in terms of the general spatial focusing, trade zoning and trade partnership is detected through the analyses in this chapter. This stabilized spatial pattern of U.S. interstate commodity flows are summarized into several major geographical clusters centered on: (1) California serving the West as well as the entire U.S., (2) Texas mainly serving the South West, (3) the Midwest represented by Illinois, Indiana, Michigan, and Ohio, (4) the Middle Atlantic represented by New York, New Jersey and Pennsylvania mainly serving the East and the Midwest, and (5) Georgia and Florida serving the South East.

In spite of imperfect data set with its own intrinsic problems (only commodity flows are identified, ignoring service activities), this study has significance since it explores the spatial patterns and changes in the patterns of flows in the entire U.S. based on the recent flow data set over time. Even though there is a great deal of theory about the role of trade, very little of the theory has been applied to intra-country flows. Concomitantly, there has been surprisingly little analysis of the patterns of trade. This chapter deals with these issues by exploring the ways of visualizing and interpreting the spatial patterns of the U.S. interstate commodity flows across all four different time periods. The interpretation of the general patterns of the U.S. interstate trade system in the geographical and spatial context provided by this chapter will provide the basis for further analyses in the field of U.S. interstate trade study.

For future research, several plans can be proposed based on the study completed in this chapter. First, some modifications could be made in the methods employed. Secondly, other spatial analysis tools such as LISA could be employed to analyze the spatial pattern of the U.S. interstate commodity flow. Besides, another cluster analysis approach can be applied to regionalize the individual states into trade zones based on the interconnectivity among them instead of a simple spatial similarity of trade flow as applied in this study. Thirdly, the same approaches introduced in this chapter can be replicated to the new data set such as Freight Analysis Framework^2 (FAF^2) for the analysis on the U.S. interstate commodity flow pattern in 2002. With a new updated and composite data set, more commodity-specific analysis is also available. More empirical study with diverse methodologies and more composite data set could validate or refine the existing interregional trade theory. Finally, another study to sort out the distance effects in terms of transportation cost also can be developed in the basis of the empirical analysis results obtained from the study in this chapter.

While this chapter only depicted the spatial and geographical pattern of U.S. interregional trade, the next chapter explores its importance in the U.S. regional economy.

Chapter 3

The Role of Interregional Trade in the U.S. Economy

1. Introduction

Although the impact of international trade on regional economic growth has become one of the more popular topics in the field of trade economics, the study of the economic impact of interregional trade within a country has only recently attracted considerable attention. Hewings *et al.* (1997; 1998) pointed out the enormous importance of interregional trade within a country by showing that the volume of interstate trade among five Midwest states exceeded the volume of foreign trade originating from those states. The study of the role of interregional trade in the regional economic growth also draws on the same mechanism that is used to explain international trade an active agent of economic growth. At the regional level, each region has the capacity to directly or indirectly influence the growth and development of every other region. Weinhold (2002) noted that both economic and geographic spaces are important as a possible medium through which economic growth effects are distributed across regions. She defined economic space in terms of economic connections based on bilateral trade flows, and addressed the importance of trade on regional economic growth.

The most popular and common analysis conducted by many regional scientists for exploring the effect of trade on regional economic growth is multiplier analysis of the interregional economic interdependency by incorporating input-output tables into trade matrices (Miyazawa, 1960; Goodwin, 1983; Haddad, *et al.*, 1999). Haddad *et al.* (2002) measured the gains and losses of interregional trade in a cost-competitiveness approach, based on relative changes in the industrial cost and demand structures. They integrated a Machlup-Goodwin-type interregional model into a national CGE (Computational General Equilibrium) model so as to analyze the effect of trade on the economies of each state in Brazil. Hitomi *et al.* (2000) also analyzed the contribution of interregional trade to the regional output growth in Japan between 1980 and 1990 within a multiregional input-output framework. They revealed that interregional trade had played a key role in determining the level of regional output while the importance of technology itself had decreased during the years of the analysis. In order to analyze sources of regional output growth – they aimed at clarifying the source of regional output growth focusing especially on the role of interregional trade and technology – they developed a decomposition method using a Japanese multiregional input-output model.

This chapter explores the role of interregional trade in the U.S. regional economy to answer the following research questions:

1) What is the role of interregional interaction in regional economic growth?
2) Is interregional trade playing a key role in distributing the regional economic growth across regions?
3) What is the spatial pattern of the diffusion of the regional economic growth?

In order to identify the separate effects of technology change, demand change, and trade pattern change on the regional output growth within an interregional input-output (IRIO) economy system, a decomposition approach is employed. In the following Section 2, some theoretical and empirical studies using a decomposition approach within an IRIO or MRIO context are introduced. Section 3 introduces the U.S. IRIO data constructed by REAL (Regional Economics and Applications Laboratory) at UIUC (University of Illinois at Urbana-Champaign) and explains the decomposition methods to isolate the interregional trade effect from the interregional input-output coefficients (the regional analogy of the technical coefficients in national studies of structural change). Section 4 reports the analysis results based on the decomposition method that is employed. The final section summarizes the findings.

2. Decomposition techniques

Decomposition techniques in the context of input-output (I-O) analysis have been central to studies for disentangling the growth in some economic variables over time by separating the changes in say output into various constituent parts (Dietzenbacher & Los, 1998). The most common decomposition analysis within an I-O framework has been used to explain economic structural change by identifying a multitude of factors such as input growth, demand change, technological innovation or diffusion, trade pattern change, economic integration, and so forth. Skolka (1989) defined the structure decomposition analysis as "a method of distinguishing major shifts within an economy by means of comparative static changes in key sets of parameters". Feldman *et al.* (1987) analyzed the source of output growth at the U.S. national level and detected the significant role of an increase in macro economic demand in accounting for output growth. They showed that technological changes was the most important source of change for only a small number of selected industries that either grew the fastest or declined the most rapidly. However, they did not distinguish pure technology changes from the trade component in the I-O coefficients. Dewhurst (1993) introduced a method to decompose the changes in the intermediate transaction flows into five components for the Scottish economy: regional output growth effect, industrial growth effect, input effect, input mix effect, and trade effect. However, his analysis is for a single region and has not been applied to the multiregional or interregional context probably because his method requires detailed interregional or multiregional level economic data which are often very limited.

The difference in decomposition analysis applied at the national and regional levels may be that, at national level, structural change can be decomposed into technological change, change in demand and synergetic change, whereas, at the (inter)regional level, the attention of structural change should include changes in intra- and interregional dependencies (Hewings *et al*., 1998). In this context, interregional input coefficients can be decomposed into two factors: technical coefficients and interregional trade coefficients (Oosterhaven & van der Linden, 1997; Oosterhaven & Hoen, 1998). Akita (1994) proposed an extended growth factor decomposition method to identify the source of regional economic growth in Japan in an interregional I-O framework. His method mainly aimed to measure the roles played by interregional interaction in the growth of a regional economy. Oosterhaven and van der Linden (1997) introduced the income growth decomposition method instead of output growth decomposition. Their method shows a typical approach to sort out the effect of interregional trade out in an input-output framework. They decomposed the income growth into four separate parts: macro economic demand changes, pure technology changes, trade structure changes, and preference changes, and found that the micro economic demand growth is the most important component to explain the income growth. Oosterhaven and Hoen (1998) refined and developed the prior research to check the importance of aggregation level in decomposition analyses. They found different results between at an aggregate county level and at an individual sector and country level. In their study, macro economic demand growth was found to be most important factor for explaining income growth at the aggregate country level. On the other hand, five other components that had relatively small influences on the income growth at the aggregate country level showed quite large and different levels of contribution to the income growth at the sector level in an individual country. Hitomi *et al.* (2000) proposed another decomposition method to identify the contribution of interregional trade in determining the regional output level in Japan for 1980~1990. They introduced the domestic purchasing coefficient to separate the interregional trade coefficient from the regional I-O coefficient. After a close examination of the change in the interregional Leontief inverse matrix and an identification of the contributions of each decomposed factor, they concluded that interregional trade has played an important role in generating changes in the regional economic growth.

3. Data and methodology of decomposition

3.1. The U.S. Multi-Region Econometric Input-Output Model data

This chapter utilizes the base year data of the Midwest Regional Econometric Input-Output Model (MWREIM) developed by REAL at UIUC. There are two different versions of model, one for 1992 and the other for 2007. The base year data contains the information on the intermediate transactions, regional sectoral output level and final demand. In particular, the newly constructed 2007 MW REIM has a multiregional social accounting matrix as its base and thus contains a much richer set of information covering very detailed composition of regional final demand and the regional flows of the final demand as well as input information and regional level international trade information. The geographical coverage of the both data is the five Midwest states of Illinois, Indiana, Michigan, Ohio, and Wisconsin with the rest of the United States (RUS) aggregated into a sixth region. For this study, two different sectoral classifications for both base year data set were adjusted to be compatible and this resulted in an aggregation to six sectors. The description of each sector and the corresponding sectors defined in the 1992 MW-IRIO matrix and 2007 MW-MRSAM are summarized in Table 3-1.

Table 3-1. Classification of economic sectors for the IRIO-based decomposition analysis in this study

Code	Description	MW REIM 1992	MW REIM 2007
1	Agriculture, Forestry, Fish & Hunting	01	01
2	Mining	02	02-04
3	Construction	03	08
4	Nondurable Manufacturing (including Food, Beverage, Tobacco, Textile, Apparel, Leather, Paper, and Chemical Products, *etc.*)	04, 05, 11	09-12
5	Durable Manufacturing (including Primary Metal & Metal Product, Machinery & Equipments, Wood, Furniture, *etc.*)	06-10, 12	13-15
6	Services(including Utilities, Government services)	13	05-07,16-24

3.2. Regional output growth decompositions

This section describes the method of decomposition applied to analyze the sources of regional output growth by distinguish the role of interregional trade and that of technology in the interregional dependency of regional economy among five U.S. Midwestern states and the rest of the United States.

3.2.1. Interregional input-output model

The basic interregional input-output model with n sectors and m regions for a static national system of economic regions is written as follows:

$$x_i^r = \sum_{s=1}^{m}\sum_{j=1}^{n} a_{ij}^{rs} x_j^s + f_i^r \quad \text{for all } i, j \in N, \text{ and } s, r \in M \tag{1}$$

where

$x_i^r =$ gross output of sector i in region r

$a_{ij}^{rs} =$ the amount of input from sector i in region r that is needed per dollar's worth of output sector j in region s (the interregional input-output coefficients)

$f_i^r =$ the amount of delivered sector i produced in region r for the final use

Equation (1) indicates that total gross output of sector i in region r is delivered to domestic intermediate and final users in all regions (including itself) within the whole economic system as well as final users of its international markets. In order to separate the effects of change in the interregional trade coefficients from the technological coefficients, the interregional input-output coefficients in equation (1) are written as the product of trade coefficients and technical coefficients based on equation (2).

$$a_{ij}^{rs} = t_{ij}^{rs} a_{ij}^{\bullet s} \tag{2}$$

where t_{ij}^{rs} is the trade coefficient indicating the fraction of the intermediate demand for sector i provided from region r to produce sector j in region s, and $a_{ij}^{\bullet s}$ is the pure technical coefficients indicating the total need for sector i from all regions of origin per unit of output of sector j in region s. Then, equation (1) can be rewritten by inserting equation (2) in as follows:

$$x_i^r = \sum_{s=1}^{m}\sum_{j=1}^{n} t_{ij}^{rs} a_{ij}^{\bullet s} x_j^s + f_i^r \quad \text{for all } i, j \in N \text{ and } s, r \in M \tag{3}$$

Matrix notations transform equation (3) into:

$$X = T \otimes AX + F \tag{4}$$

where

$X =$ NM-column with gross output per sector and per region
$T =$ NM $\times$ NM-matrix of trade coefficients for intermediate demand (t_{ij}^{rs})
$A =$ NM $\times$ NM-matrix, built up of M mutually identical N $\times$ NM-matrices with technical coefficients ($a_{ij}^{\bullet s}$)
$F =$ NM-column with final demand per sector and per regions
$\otimes$ = Hadamar product, i.e. element by element multiplication

The structure of these sub-matrices is summarized as follows:

$$\begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^6 \end{pmatrix} = \begin{pmatrix} T^{11} & T^{12} & \cdots & T^{16} \\ T^{21} & T^{22} & \cdots & T^{26} \\ \vdots & \vdots & \ddots & \vdots \\ T^{61} & T^{62} & \cdots & T^{66} \end{pmatrix} \otimes \begin{pmatrix} A^1 & A^2 & \cdots & A^6 \\ A^1 & A^2 & \cdots & A^6 \\ \vdots & \vdots & \ddots & \vdots \\ A^1 & A^2 & \cdots & A^6 \end{pmatrix} \begin{pmatrix} X^1 \\ X^2 \\ \vdots \\ X^6 \end{pmatrix} + \begin{pmatrix} F^1 \\ F^2 \\ \vdots \\ F^6 \end{pmatrix} \tag{5}$$

Where X^r is an output vector in region *r*, T^{rs} is an interregional trade coefficient matrix representing interregional intermediate delivery flows from region *r* to region *s*, A^s is a technical coefficient matrix in region *s*, and F^r is a final demand vector in region *r*. Furthermore, these sub-matrices are written in full as follows:

$$T^{rs} = \begin{pmatrix} t_{11}^{rs} & t_{12}^{rs} & \cdots & t_{16}^{rs} \\ t_{21}^{rs} & t_{22}^{rs} & \cdots & t_{26}^{rs} \\ \vdots & \vdots & \ddots & \vdots \\ t_{61}^{rs} & t_{62}^{rs} & \cdots & t_{66}^{rs} \end{pmatrix}, A^s = \begin{pmatrix} a_{11}^{s} & a_{12}^{s} & \cdots & a_{61}^{s} \\ a_{21}^{s} & a_{22}^{s} & \cdots & a_{62}^{s} \\ \vdots & \vdots & \ddots & \vdots \\ a_{61}^{s} & a_{62}^{s} & \cdots & a_{66}^{s} \end{pmatrix}, X^r = \begin{pmatrix} x_1^r \\ x_2^r \\ \vdots \\ x_6^r \end{pmatrix}, F^r = \begin{pmatrix} f^1 \\ f^2 \\ \vdots \\ f^6 \end{pmatrix} \tag{6}$$

From equation (4), the regional output vector *X* can be solved:

$$X = (I - T \otimes A)^{-1} F \tag{7}$$

Equation (7) shows that the regional output *X* is determined by the production induced by regional final demand.

3.2.2. Decomposition of ΔX

Equation (4) reveals that intraregional interindustry commodity flows are allocated interregionally through the interregional trade components in the interregional input-output framework. In particular, equation (7) indicates that changes in the interregional coefficients will affect changes in X through changes in the enlarged Leontief inverse and changes in the regional final demand. The increase in total regional output between two time points (subscripts t=0 and t=1) can be written as:

$$\begin{aligned}\Delta X &= X_1 - X_0 \\ &= (I - T_1 \otimes A_1)^{-1} F_1 - (I - T_0 \otimes A_0)^{-1} F_0 \\ &= B_1 F_1 - B_0 F_0\end{aligned} \tag{8}$$

where $B = (I - T \otimes A)^{-1}$.

Equation (6) can be expressed in four different ways:

$$B_1 F_1 - B_0 F_0 = \Delta B F_0 + B_1 \Delta F \tag{8.1}$$

$$= \Delta B F_1 + B_0 \Delta F \tag{8.2}$$

$$= \Delta B F_0 + B_0 \Delta F + \Delta B \Delta F \tag{8.3}$$

$$= \Delta B F_1 + B_1 \Delta F - \Delta B \Delta F \tag{8.4}$$

where $\Delta B = B_1 - B_0$ and $\Delta F = F_1 - F_0$.

When a decomposition is made for discrete time periods as in this study, the infinitesimal derivation is theoretically incorrect as it neglects the combined differences components, *i.e.* it neglects the last term in (8.3) and (8.4) (Oosterhaven & Hoen, 1998, Hitomi, *et al.*, 2000). Therefore, the arithmetic average of (8.1) and (8.2) has been chosen[10]:

10 This average is also equal to the arithmetic average of (8.3) and (8.4). This averaging procedure will be employed whenever a similar problem occurs during the decomposition process.

$$\Delta X = \frac{1}{2}\Delta B(F_0 + F_1) + \frac{1}{2}(B_0 + B_1)\Delta F \qquad (9)$$

Equation (9) can be decomposed further by decomposing the component of ΔB.

For the subsequent decomposition of changes in the enlarged Leontief inverse matrix (ΔB), the approach shown in Akita (1993) is employed in equation (9). It turns out that the term $\Delta(T \otimes A)$ plays a key role in explaining the changes in the enlarged interregional Leontief inverse.

$$\Delta B = B_1 - B_0 = B_1((B_0)^{-1} - (B_1)^{-1})B_0 = B_1(\Delta(T \otimes A))B_0 \qquad (10)$$

$$\Delta(T \otimes A) = \frac{1}{2}\left[(T_0 + T_1) \otimes \Delta A\right] + \frac{1}{2}\left[\Delta T \otimes (A_0 + A_1)\right] \qquad (11)$$

Substituting (10) into (11), the change in the enlarged Leontief inverse can be written as:

$$\Delta B = \frac{1}{2}B_1\left[(T_0 + T_1) \otimes \Delta A\right]B_0 + \frac{1}{2}B_1\left[\Delta T \otimes (A_0 + A_1)\right]B_0 \qquad (12)$$

According to (12), the actual changes in the technical coefficients (ΔA) as well as those in the trade coefficients (ΔT) have impacts on the enlarged Leontief inverse. The first part of (12) indicates the impact of ΔA, whereas the second part shows the impact of ΔT, respectively.

By substituting (12) into (9), the following decomposition of ΔX is given with four terms of B, F, A, and T:

$$\begin{aligned}\Delta X &= \frac{1}{2}(B_0 + B_1)\Delta F \\ &+ \frac{1}{4}B_1\left[(T_0 + T_1) \otimes \Delta A\right]B_0(F_0 + F_1) \\ &+ \frac{1}{4}B_1\left[\Delta T \otimes (A_0 + A_1)\right]B_0(F_0 + F_1)\end{aligned} \qquad (13)$$

According to (13), the changes in regional total output can be decomposed into three different factors: change in regional final demand (ΔF), change in regional technical coefficient (ΔA), and change in interregional trade coefficient for intermediate goods (ΔT).

In order to simplify the comparison of the changes in each component, the block total multipliers (block multiplier, hereafter) defined as follows are examined (Hitomi *et al.*, 2000):

$$V^{rs} = \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij}^{rs} \tag{14}$$

where b_{ij}^{rs} = the element of the subject component matrix.

This expression is interpreted as a summation of the column multiplier with regard to sectors at a specific interregional block-region *r* and region *s*. The value of this block multiplier indicates the overall magnitude of direct and indirect effects for a specific interregional relationship. Based on the notation of (14), the difference of the block multiplier between two time periods (subscripts *t*=1 and *t*=0) is defined as:

$$\Delta V^{rs} = V_1^{rs} - V_0^{rs}. \tag{15}$$

4. Results

4.1. Change in the enlarged Leontief inverse matrix and the role of interregional trade

Since the change in the enlarged Leontief inverse is defined as in equation (12), the difference in the block multiplier is decomposed into two parts: contribution of interregional trade coefficients and contribution of technical coefficients. The difference in the enlarged Leontief inverse between 1992 and 2007 in Figure 3-1 shows the changes in the enlarged Leontief inverse between two analysis years.

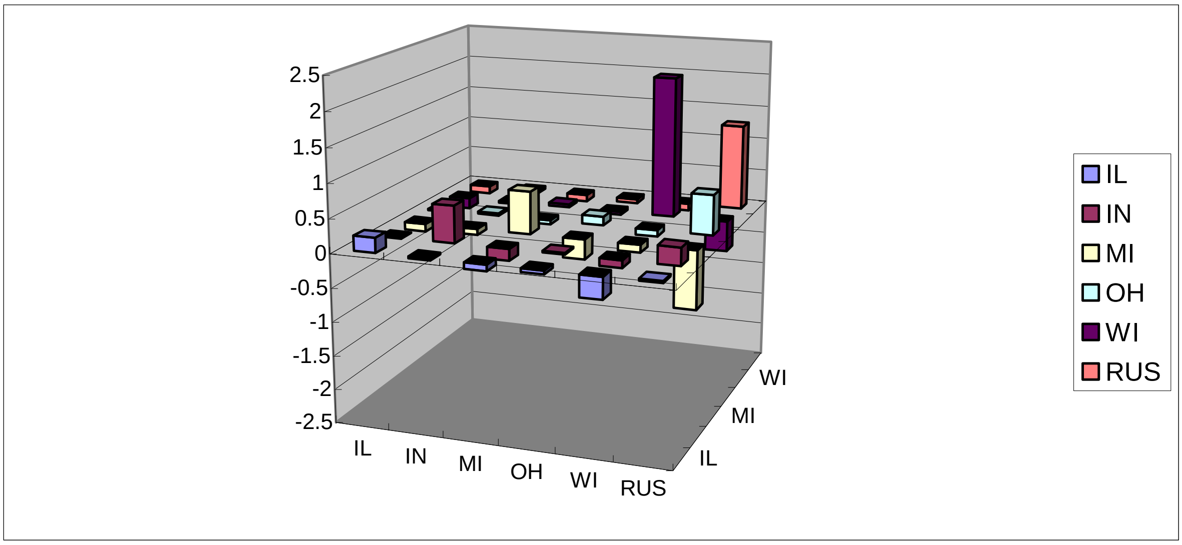

Figure 3-1. Difference in the enlarged Leontief inverse, 1992~2007
Data source: 1992 and 2007 MWREIM

The increase in the *intra*regional multipliers over time is observed while most interregional multipliers show the decreases. In particular, the relatively large increase in the *intra*regional multiplier of Wisconsin is notable. Whereas the interregional multipliers among five Midwestern states are observed decreased between 1992 and 2007, the interregional multipliers of Ohio, Indiana, and Illinois to the RUS have increased. However, those of Michigan and Wisconsin represent negative growth. Since there is no intermediate data between two years, the average annual trend between 1992 and 2007 cannot be tracked. This difference compares only two discrete years. Figures 3-2 and 3-3 show two different coefficient components that contribute to the changes in the enlarged Leontief inverse. Figure 3-2 and 3-3 indicate how much coefficient effect of technology and interregional trade can explain the changes in the enlarged Leontief inverse between two years, respectively. These two figures enable us to decompose each coefficient's effect in determining the level of changes in the enlarged Leontief inverse in 1992 and 2007. For example, the large changes in the enlarged Leontief inverse for Wisconsin itself can be explained more by the interregional trade effect rather than the technical coefficient effect. Over the years, the more positive contribution of the technical coefficient to the change in the enlarged Leontief inverse is observed. However, the contribution of interregional trade coefficients to the enlarged Leontief inverse appears to be greater in a negative direction. This does not imply that interregional trade effect is more important than technical effect in generating the regional economic growth level or vice versa. The results show that interregional trade coefficient effect has larger magnitude (in a negative direction for the most part) of influence on determining the negative interregional economic multipliers compared to technical coefficient effect. Such a finding might imply that these five Midwestern states play significant roles not only within the Midwest but also in the whole U.S. This analysis applies a six-region analysis frame which covers five Midwestern states and one aggregate region that encompass the rest 45 U.S. states. In other words, the interregional trade effect might be under-evaluated relatively because of the spatial scale of this analysis. If more disaggregate and detailed regional data were available, different results would say different stories. For a more detailed picture of the effects of technology and interregional trade patterns on the regional output growth, further disaggregated analysis should be conducted for the future.

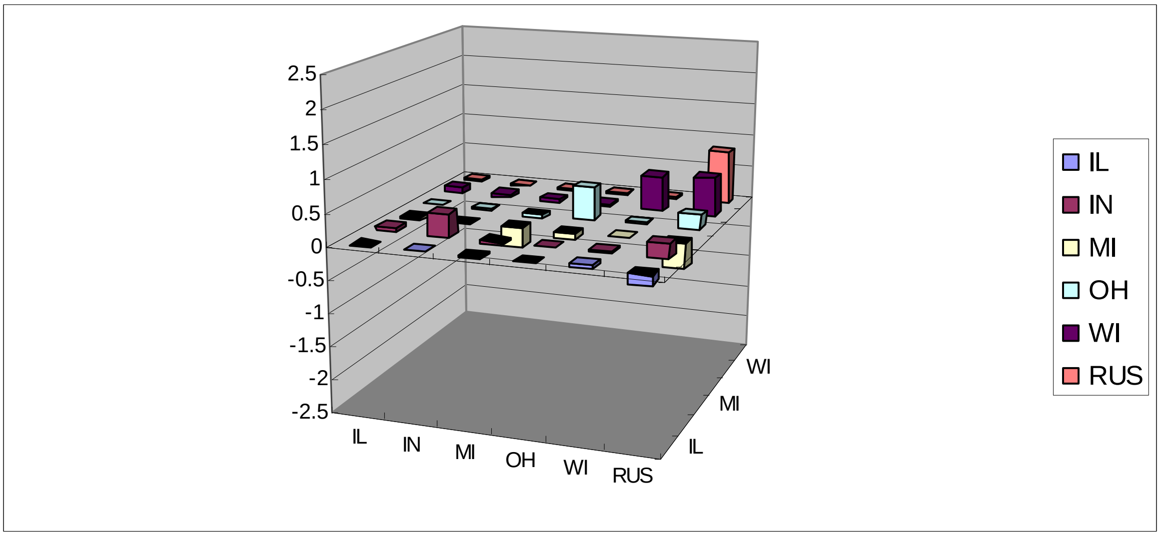

Figure 3-2. Contribution of technical coefficients to the changes in the enlarged Leontief inverse, 1992~2007
Data source: 1992 and 2007 MWREIM

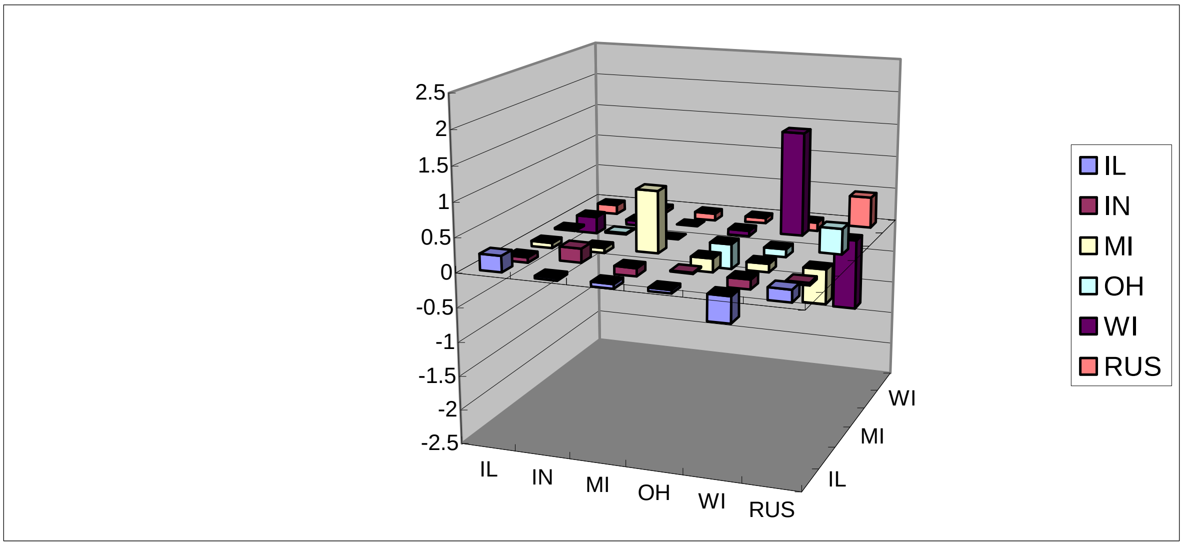

Figure 3-3. Contribution of interregional trade coefficients to the changes in the enlarged Leontief inverse, 1992~2007
Data source: 1992 and 2007 MWREIM

4.2. Change in the Regional Output

Based on equations (9) and (13), the changes in both the enlarged Leontief inverse and the final demand (including international trade) are combined to examine the contribution to the growth of regional output level. Table 3-2 shows the contributions of each component to the changes in the regional output level for each region.

Table 3-2. Contributions of each component to the regional output changes in each region, 1992~2007

	Final demand effect (C1)	Technology effect (C2)	Trade effect (C3)	Total effect*	C1	C2	C3	Total
	Absolute effect				Contribution ratio			
Illinois	451083.32	48843.81	-174640.02	325287.10	138.7%	15.0%	-53.7%	100.0%
Indiana	189325.88	34651.93	-67015.74	156962.07	120.6%	22.1%	-42.7%	100.0%
Michigan	277489.12	-16801.66	-120363.57	140323.88	197.7%	-12.0%	-85.8%	100.0%
Ohio	305802.62	54594.75	-161998.11	198399.26	154.1%	27.5%	-81.7%	100.0%
Wisconsin	195936.36	49713.21	-149711.21	95938.36	204.2%	51.8%	-156.0%	100.0%
RUS	7838325.57	1156834.78	588401.07	9583561.43	81.8%	12.1%	6.1%	100.0%
U.S.	10677600.17	1498838.85	-759056.23	11417382.77	93.5%	13.1%	-6.6%	100.0%

Note: Total effect* denotes the total changes in the aggregate regional output between 1992 and 2007
Data source: 1992 and 2007 MWREIM

Each component is defined as follows: the final demand effect (C1), the technical coefficient effect or technology effect (C2), and the interregional trade effect (C3). The component explained by the change in final demand (C1) proves to be the most influential component for the entire U.S. economy between 1992 and 2007. The next contribution component is technology effect, which is followed by the interregional trade effect. In particular, the interregional trade component affects the U.S. output changes between 1992 and 2007 in a negative way. When looking more closely into the interregional trade effect for each region, the effects of five Midwestern states show very large negative magnitude. As mentioned above, it might spatial scale problem of this study. Still, this finding shows that the interregional trade has a huge influence on determining the regional output growth level even in a negative direction and it implies that each region has a potential to boost its regional output growth level by promoting the interregional trade.

For the final demand effect, each individual region also shows the same pattern; the final demand effects are most significant. Related to the technology effects, the regional average contribution to the regional output change is negative only in Michigan. In other regions, the technology effects are positive, which is consistent with the global pattern of the entire U.S. The interregional trade effects in each region are more varied. In the all Midwest states, the interregional trade effect appears negative and the magnitudes of effects are much greater than the technology effect. In essence, the interregional trade effect has the second most significant influence on determining the regional output level in the Midwest region when we look into the contribution of each composite component. This pattern is more remarkable in Wisconsin. In Wisconsin, the final demand component has the greatest contribution to the regional output change between 1992 and 2007. At the same time, notice that interregional trade effect is almost comparable in size with the final demand effect but in the opposite direction.

Table 3-3. Economic factor contribution to aggregated regional output growth, 1992~2007

	ΔF (%)	ΔA (%)	ΔT (%)	Total (%)*
Region	Change rate, 1992~2007			
Illinois	-39.0	-7.0	-75.2	-121.2
Indiana	-44.3	6.5	-60.1	-97.8
Michigan	-53.8	-13.3	-77.3	-144.4
Ohio	-56.5	7.2	-55.9	-105.1
Wisconsin	-38.4	15.4	-79.4	-102.4
RUS	-35.1	15.6	12.5	-6.9
US	-38.4	2.9	0.0	-35.5
	Contribution ratio, 1992~2007			
Illinois	32.2	5.8	62.0	100.0
Indiana	45.3	-6.7	61.4	100.0
Michigan	37.3	9.2	53.6	100.0
Ohio	53.7	-6.9	53.2	100.0
Wisconsin	37.5	-15.1	77.6	100.0
RUS	506.0	-225.5	-180.4	100.0
US	108.0	-8.0	0.0	100.0

Note 1: ΔF-change in final demand including international trade at the corresponding region, ΔA-change in technical coefficient, and ΔT-change in interregional trade coefficient.
Note 2: All the economic factor level is considered in the 2007 U.S. dollar level.
Note 3: Total (%)* in the upper part of this table does not indicate the decrease in the total regional output level. It is the simple sum of the changes in the three factors. In fact, the total regional outputs have increased in all the six regions over the years of study, 1992~2007.
Data source: 1992 and 2007 MWREIM

Table 3-3 shows the each individual economic factor's contribution to regional output growth. The upper part of the table shows the actual growth rates of each economic factor in each region between 1992 and 2007. The lower level shows the contribution to the aggregate regional output growth for each economic factor. The most notable outcome is that the changes in interregional trade coefficients in the Midwest show an important contribution to the aggregate regional output growth in all five Midwest states except Ohio. In Ohio, the contribution ratios of final demand change as well as interregional trade coefficient change are almost identical. In the Midwest, the interregional trade among five states as well as with the

RUS has had an important impact in determining the total output level in each state between 1992 and 2007. However, this pattern is quite different from that of the RUS and the average pattern of the entire U.S. In the RUS and the U.S., the final demand change has the largest impact in generating the regional output growth. This pattern in the Midwest suggests that there might be distinguishing factors or underpinning forces explaining the economic structure in the Midwest related to the output level changes over the years of 1992 and 2007. For this reason, there is a need to examine the more detailed picture at a disaggregated sectoral level.

Table 3-4 shows the contribution of each component to the regional output growth based on the equation (13) at a disaggregated sectoral level in each region. The first thing to note is that the output growth in the service sector (sector 6) is remarkable in all the regions between 1992 and 2007. For the service sector, the final demand effects have the most significant contribution as expected. The output level of the nondurable manufacturing sector in Illinois decreased over the time period (1992-2007) and the dominant source of explanation would appear to be final demand. However, the interregional trade effect also contributes significantly to the output changes and even in a positive direction. Notwithstanding some variations, the final demand effects have the positive impacts and the interregional trade effects have the negative impacts on the regional and sectoral output growth throughout the regions. However, the magnitude of effect varies within a great range. In contrast to these two components, the technology effects reveal a more diverse pattern over the regions and by sector. In addition, the interregional trade effect accounts for the regional output changes more than the technical coefficient effect on average – even at a disaggregated sectoral level.

Table 3-4. Each component's contributions to regional output changes in each region by sector, 1992~2007

Region	Sector	Absolute contribution effects				Contribution ratio			
		Final demand effect (C1)	Technology effect (C2)	Trade effect (C3)	Total effect*	C1	C2	C3	Total**
Illinois	1	4931.75	-440.87	-4208.71	282.17	1747.8%	-156.2%	-1491.6%	100.0%
	2	3312.54	7147.60	-4704.64	5755.49	57.6%	124.2%	-81.7%	100.0%
	3	39382.04	-12199.75	-13083.24	14099.04	279.3%	-86.5%	-92.8%	100.0%
	4	-5078.97	32871.90	-23844.19	3948.74	-128.6%	832.5%	-603.8%	100.0%
	5	40273.08	-15100.62	-25619.49	-447.03	-9009.1%	3378.0%	5731.1%	100.0%
	6	368262.88	36565.56	-103179.75	301648.68	122.1%	12.1%	-34.2%	100.0%
	Total	451083.32	48843.81	-174640.02	325287.10	138.7%	15.0%	-53.7%	100.0%
Indiana	1	3668.03	420.53	-199.06	3889.50	94.3%	10.8%	-5.1%	100.0%
	2	1290.57	2427.36	-2655.65	1062.28	121.5%	228.5%	-250.0%	100.0%
	3	16227.98	-5088.90	-3115.62	8023.45	202.3%	-63.4%	-38.8%	100.0%
	4	7485.81	22481.98	-15788.25	14179.55	52.8%	158.6%	-111.3%	100.0%
	5	53436.44	-14794.82	-10928.90	27712.71	192.8%	-53.4%	-39.4%	100.0%
	6	107217.05	29205.78	-34328.25	102094.58	105.0%	28.6%	-33.6%	100.0%
	Total	189325.88	34651.93	-67015.74	156962.07	120.6%	22.1%	-42.7%	100.0%
Michigan	1	1335.37	1092.18	-721.41	1706.13	78.3%	64.0%	-42.3%	100.0%
	2	1724.58	3954.58	-3706.56	1972.60	87.4%	200.5%	-187.9%	100.0%
	3	17615.24	-10605.66	-1313.15	5696.43	309.2%	-186.2%	-23.1%	100.0%
	4	-16490.41	14099.55	-9088.54	-11479.40	143.7%	-122.8%	79.2%	100.0%
	5	93982.96	-41891.38	-69254.49	-17162.91	-547.6%	244.1%	403.5%	100.0%
	6	179321.38	16549.06	-36279.41	159591.03	112.4%	10.4%	-22.7%	100.0%
	Total	277489.12	-16801.66	-120363.57	140323.88	197.7%	-12.0%	-85.8%	100.0%
Ohio	1	2002.24	1072.29	-3431.93	-357.40	-560.2%	-300.0%	960.3%	100.0%
	2	2759.28	4931.31	-5676.44	2014.15	137.0%	244.8%	-281.8%	100.0%
	3	16056.96	-6973.81	-2420.11	6663.04	241.0%	-104.7%	-36.3%	100.0%
	4	2573.26	29307.98	-16477.45	15403.80	16.7%	190.3%	-107.0%	100.0%
	5	68455.73	-28265.75	-61897.23	-21707.25	-315.4%	130.2%	285.1%	100.0%
	6	213955.14	54522.73	-72094.94	196382.93	108.9%	27.8%	-36.7%	100.0%
	Total	305802.62	54594.75	-161998.11	198399.26	154.1%	27.5%	-81.7%	100.0%
Wisconsin	1	2807.20	6052.16	-5290.12	3569.25	78.6%	169.6%	-148.2%	100.0%
	2	408.43	1408.44	-1526.21	290.66	140.5%	484.6%	-525.1%	100.0%
	3	-32834.41	-5621.79	3282.87	-35173.33	93.4%	16.0%	-9.3%	100.0%
	4	19888.18	34112.78	-50723.13	3277.83	606.7%	1040.7%	-1547.5%	100.0%
	5	51630.22	-5912.54	-31341.44	14376.24	359.1%	-41.1%	-218.0%	100.0%
	6	154036.74	19674.15	-64113.18	109597.71	140.5%	18.0%	-58.5%	100.0%
	Total	195936.36	49713.21	-149711.21	95938.36	204.2%	51.8%	-156.0%	100.0%
RUS	1	12567.28	-38695.60	9599.90	-16528.41	-76.0%	234.1%	-58.1%	100.0%
	2	209511.77	36393.05	16749.36	262654.18	79.8%	13.9%	6.4%	100.0%
	3	743291.13	-92862.87	16176.14	666604.40	111.5%	-13.9%	2.4%	100.0%
	4	285392.40	258747.98	98997.31	643137.68	44.4%	40.2%	15.4%	100.0%
	5	311110.23	-133615.58	164699.34	342193.98	90.9%	-39.0%	48.1%	100.0%
	6	6276452.76	1126867.80	282179.03	7685499.58	81.7%	14.7%	3.7%	100.0%
	Total	7838325.57	1156834.78	588401.07	9583561.43	81.8%	12.1%	6.1%	100.0%
US	Total	10677600.17	1498838.85	-759056.23	11417382.77	93.5%	13.1%	-6.6%	100.0%

Note: Total effect* and Total** denote the sum of the three effects and their contribution ratios, respectively.
Data source: 1992 and 2007 MWREIM

Table 3-5. Economic factor contribution to aggregated regional output growth, 1992~2007

		Change rate (%)				Contribution ratio			
Region	Sector	ΔF	ΔA	ΔT	ΔF+ΔA+ΔT	ΔF	ΔA	ΔT	Total
Illinois	01	108.6%	-20.2%	-50.2%	38.2%	284.5%	-52.9%	-131.6%	100.0%
	02	3858.7%	122.2%	-48.4%	3932.5%	98.1%	3.1%	-1.2%	100.0%
	03	12.8%	-34.9%	90.4%	68.3%	18.7%	-51.2%	132.5%	100.0%
	04	-124.2%	87.3%	-19.9%	-56.8%	218.6%	-153.7%	35.1%	100.0%
	05	-77.1%	-26.9%	-33.0%	-136.9%	56.3%	19.6%	24.1%	100.0%
	06	-2.9%	-0.1%	25.1%	22.0%	-13.3%	-0.4%	113.7%	100.0%
	Total	-39.0%	15.6%	-75.2%	-98.5%	39.6%	-15.9%	76.3%	100.0%
Indiana	01	316.4%	-20.2%	6.9%	303.0%	104.4%	-6.7%	2.3%	100.0%
	02	2331.2%	122.2%	-35.2%	2418.2%	96.4%	5.1%	-1.5%	100.0%
	03	-13.9%	-34.9%	79.0%	30.1%	-46.0%	-115.9%	261.9%	100.0%
	04	-108.1%	87.3%	-15.9%	-36.7%	294.5%	-237.7%	43.3%	100.0%
	05	-44.6%	-26.9%	13.4%	-58.1%	76.8%	46.3%	-23.1%	100.0%
	06	-26.9%	-0.1%	27.7%	0.6%	-4188.3%	-14.3%	4302.7%	100.0%
	Total	-44.3%	15.6%	-60.1%	-88.7%	49.9%	-17.6%	67.7%	100.0%
Michigan	01	-1.7%	-20.2%	16.6%	-5.3%	31.8%	381.0%	-312.9%	100.0%
	02	4058.3%	122.2%	-48.6%	4132.0%	98.2%	3.0%	-1.2%	100.0%
	03	-42.9%	-34.9%	259.9%	182.1%	-23.5%	-19.2%	142.7%	100.0%
	04	-139.1%	87.3%	-4.9%	-56.7%	245.4%	-154.0%	8.6%	100.0%
	05	-14.9%	-26.9%	-20.6%	-62.4%	23.9%	43.1%	33.0%	100.0%
	06	-38.4%	-0.1%	63.5%	25.0%	-153.7%	-0.4%	254.1%	100.0%
	Total	-53.8%	15.6%	-77.3%	-115.5%	46.6%	-13.5%	67.0%	100.0%
Ohio	01	-17.5%	-20.2%	-16.6%	-54.2%	32.2%	37.2%	30.6%	100.0%
	02	3322.2%	122.2%	-49.0%	3395.5%	97.8%	3.6%	-1.4%	100.0%
	03	-63.7%	-34.9%	68.4%	-30.2%	210.7%	115.6%	-226.3%	100.0%
	04	-115.0%	87.3%	-5.5%	-33.2%	346.1%	-262.7%	16.6%	100.0%
	05	-64.2%	-26.9%	-20.8%	-111.9%	57.4%	24.0%	18.6%	100.0%
	06	-33.6%	-0.1%	7.3%	-26.4%	127.1%	0.3%	-27.5%	100.0%
	Total	-56.5%	15.6%	-55.9%	-96.7%	58.4%	-16.2%	57.8%	100.0%
Wisconsin	01	140.9%	-20.2%	53.6%	174.3%	80.8%	-11.6%	30.8%	100.0%
	02	3747.3%	122.2%	-79.9%	3789.6%	98.9%	3.2%	-2.1%	100.0%
	03	-158.3%	-34.9%	236.6%	43.4%	-364.3%	-80.5%	544.8%	100.0%
	04	-80.1%	87.3%	-33.3%	-26.1%	306.8%	-334.3%	127.4%	100.0%
	05	59.8%	-26.9%	-9.7%	23.2%	257.7%	-115.9%	-41.8%	100.0%
	06	77.8%	-0.1%	201.3%	278.9%	27.9%	0.0%	72.2%	100.0%
	Total	-38.4%	15.6%	-79.4%	-102.2%	37.6%	-15.3%	77.7%	100.0%
RUS	01	-116.7%	-20.2%	2.6%	-134.2%	86.9%	15.0%	-2.0%	100.0%
	02	520.8%	122.2%	58.5%	701.5%	74.2%	17.4%	8.3%	100.0%
	03	12.8%	-34.9%	-73.1%	-95.2%	-13.5%	36.7%	76.8%	100.0%
	04	-101.4%	87.3%	73.2%	59.1%	-171.6%	147.7%	123.9%	100.0%
	05	-95.6%	-26.9%	30.1%	-92.4%	103.5%	29.1%	-32.6%	100.0%
	06	-11.0%	-0.1%	-35.5%	-46.6%	23.6%	0.2%	76.2%	100.0%
	Total	-35.1%	15.6%	12.5%	-6.9%	506.0%	-225.5%	-180.4%	100.0%
US	Total	-38.4%	2.9%	0.0%	-35.5%	108.0%	-8.0%	0.0%	100.0%

Data source: 1992 and 2007 MWREIM

5. Conclusion

This chapter conducted a decomposition approach to identify the role of the interregional trade in generating the regional output within a U.S. six-region interregional input-output framework. The decomposition formula is based on the basic interregional input-output model and separates the interregional trade coefficient and pure technical coefficient from the interregional input-output coefficient. This decomposition highlights the contribution of each factor - final demand, technical coefficient, and interregional trade coefficient – to the regional output growth through both interregional and intersectoral feedback linkages.

The empirical study on the U.S. Midwest regions and the RUS between 1992 and 2007 reveals that interregional trade effect played an important role in changes in the enlarged Leontief inverse matrix as well as in the regional output level over time. On average, the final demand effects are dominant in explaining regional output growth.

This study is based on the idea that the attention of structural change should include changes in interregional dependencies at regional level (Hewings *et al.*, 1998). Therefore, decomposition methods that were employed sorted out the interregional trade coefficient from the original interregional input-output coefficient. However, the interregional trade coefficient is separately modeled only for intermediate demand, not for the final demand; this limitation was imposed by the available data set. With a richer data set for the composition of the regional final demand as well as on the regional international trade, the decomposition method could be refined more to include the interregional trade coefficient to detect the interregional trade effects in the final demand distributions across the regions as well.

A more advanced version of decomposition method for the regional output growth can be proposed. The basic idea is based on the approach of Oosterhaven and Hoen (1998). They decomposed the factors that influenced the value-added growth. However, this could be modified to analyze the output growth instead. The advanced decomposition formula from the model applied in this study can be induced within a basic interregional input-output model with *n* sectors, *m* regions and *h* categories of final demand as follows:

$$x_i^r = \sum_{s=1}^{m}\sum_{j=1}^{n} a_{ij}^{rs} x_j^s + \sum_{s=1}^{m}\sum_{k=1}^{h} f_{ik}^{rs} + e_i^r \quad \text{for all } i, j \in N,\ s, r \in M \text{ and } k \in H \tag{16}$$

where

f_{ik}^{rs} = the amount of delivered of sector i produced in region r for type k final use in region s
e_i^r = exports of sector i from region r to international market

In addition to the decomposition of interregional input-output coefficient as in equation (2), two other coefficients can be introduced as:

$$f_{ik}^{rs} = t_{ik}^{rs} f_{ik}^{\bullet s} \tag{17}$$

where t_{ik}^{rs} is the trade coefficient that indicates the fraction of final demand for product *i* from region *r* to meet the final demand in the category (type) *k* final demand in region *s*. $f_{ik}^{\bullet s}$ is the preference coefficient indicating the total need for products from sector *i* over all the origins, per unit of final demand of category *k* in region *s*. Then, equation (17) is expanded and can be expressed in a matrix notation as equation (18): $X = T^a \otimes AX + T^f \otimes F + E$ (18)

where

T^a = NM × NM-matrix of trade coefficients for intermediate demand (t_{ij}^{rs})
T^f = NM × HM-matrix of trade coefficeints for the final demand per category (t_{ik}^{rs})
E = NM-matrix with international exports per sector and per region

Then, the regional output vector *X* can be solved as equation (18) and decomposed into two parts, one is explained by the final demand-induced effect and the other by the international export-induced effect:

$$X = (I - T^a \otimes A)^{-1}(T^f \otimes F + E)$$
$$= (I - T^a \otimes A)^{-1}(T^f \otimes F) + (I - T^a \otimes A)^{-1}E = X^f + X^e \quad (19)$$

In this model, the growth of regional output is expressed as: $\Delta X = \Delta X^f + \Delta X^e$ (20)

Then, based on the same logic and procedures employed in this study, the following final decomposition equation for the regional output growth can be proposed as follows:

$$\begin{aligned}
\Delta X = & \frac{1}{4}(B_0 + B_1)\left[(T_0^f + T_1^f) \otimes \Delta F\right] \\
& + \frac{1}{2}(B_0 + B_1)\Delta E \\
& + \frac{1}{4}B_1\left[(T_0^a + T_1^a) \otimes \Delta A\right]B_0\left[(T_0^f \otimes F_0) + (T_1^f \otimes F_1) + (E_0 + E_1)\right] \\
& + \frac{1}{4}B_1\left[\Delta T^a \otimes (A_0 + A_1)\right]B_0\left[(T_0^f \otimes F_0) + (T_1^f \otimes F_1) + (E_0 + E_1)\right] \\
& + \frac{1}{4}(B_0 + B_1)\left[\Delta T^f \otimes (F_0 + F_1)\right]
\end{aligned} \quad (21)$$

Therefore, the changes in regional output can be explained by five different factors: change in regional final demand (ΔF),change in international exports for each region (ΔE), change in regional technical coefficient (ΔA), change in interregional trade coefficient for intermediate goods (ΔT^a), and change in interregional trade coefficient for final demand allocation (ΔT^f).Such a modification with more detailed data will be possible and will provide richer insights into the growth accounting process. This modification enables provides the opportunity to understand regional economic interdependence in much more detail by identifying each component's contribution to the regional output growth.

Future research might also explore two further directions. One option would be to see how the length of the time span affects outcomes. Hitomi *et al.* (2000) provided some insights into the importance of the temporal structural changes in the regional economic structure; however, this was only possible because Japanese interregional trade data are available every five years.

Another proposed empirical study is one which is based on the different geographical configuration to cover more comprehensively changes in trade at different spatial scales. Hewings and Parr (2002) showed that the hollowing out process observed for the Chicago metropolitan area represents a spatially-hierarchical process. In other words, the hollowing out process is evident first at a small geographic scale, for instance at the metropolitan scale, then extend to the state scale, the regional scale and then the national scale. Hence, more spatially hierarchical approach is needed to detect properly the role of interregional trade in the regional economy.

Chapter 4

Spatial Economic Interdependence in the U.S. Regional Economy: An Interregional Input-Output Approach

1. Introduction

The reawakened interest in the geographical dimensions of trade has focused attention on the factors that influence the amount and type of commodities shipped between regions, by paying special attention to the nature of spatial economic interdependence. Therefore, it is important to comprehend the interrelationship or linkages between production, distribution, and consumption among regions to understand the interregional trade pattern. The interregional input-output (IRIO) or multiregional input-output (MRIO) models based on an input-output framework facilitate the incorporation of information regarding production-related transaction flows between different sectors in different regions. Therefore, interregional and intersectoral interdependence in an economy system can be detected in the IRIO or MRIO context.

As regions become mature and economically integrated, more spatial dispersion of production across regions might be expected. Within a nation, interregional trade would be motivated more by centripetal forces produced by cumulative causation, such as the interaction of scale economies, transportation costs and specialized labor pools rather than by just comparative advantages of input costs or labor mobility (Fujita and Thisse, 1996; Krugman, 1998). This self-reinforcing process may result in greater spatial dispersion of production across regions, and production process will be more spatially complex (Hewings & Parr, 2009). Hence, it is essential to understand the spatial economic structure in terms of interregional and intersectoral interdependence for understanding the spatial pattern of interregional trade.

This chapter explores the spatial economic interdependence among five Midwest and the rest of U.S. in 2007 based on a 6-region IRIO table constructed by REAL in UIUC. The IRIO has more detailed information on the five Midwest states. Since previous studies (Hewings & Parr, 2009; Parr *et al.*, 2002; Sonis *et al.*, 2002) claimed the Midwest has a spatially-specific production structure, this study also focuses on how the regions interact and how strong the linkages are among five Midwest states and the rest of U.S. In section 2, some of the theoretical background will be provided on the combined hypothetical extraction methods to explore the nature and importance of sectors and regions in the regional economy system. Section 3 introduces the 2007 Midwest Multiregional Social Account Matrix constructed by REAL and explains the methods adopted to measure the spatial and sectoral interdependence among six regions within the U.S. Section 4 reports the empirical results from the analyses on the production-related transactions among 14 economic sectors in the six regions. The final section summarizes the major empirical findings.

2. Hypothetical extraction methods

Cella (1984) proposed an improvement on Strassert's original method. Cella (1984) defined the total linkage effects of a specific industry and then separated them into two components, backward and forward linkages. However, there are some arguments that the forward linkages might be overestimated based on the method proposed by Cella (Clements, 1990). The backward linkages of a sector reflect the sector's dependence on inputs that are produced within the production process of the economy. The forward linkages are understood by analogy to the backward linkages. That is, while the backward linkages measure the buyer's dependence from the buyer's viewpoint, the forward linkages measure the seller's dependence form the seller's viewpoint. In a sense, the backward linkages of a sector can be measured by calculating the difference between the actual production and the production in the hypothetical situation where all intermediate deliveries to the sector under consideration are extracted. In a similar manner, the forward linkages of a sector can be obtained by considering the hypothetical situation where the sector provides no intermediate deliveries to the other sectors in the system.

Based on these concepts, the backward and forward linkages are identified separately from the input coefficients matrix and the output coefficients matrix respectively. This approach can be modified to extract a region instead of a sector in an interregional framework in order to measure regional linkages (Dietzenbacher *et al.*, 1993; Perobelli *et al.*, 2003). This regional extraction examines the importance of a region by hypothetically extracting that particular region from the interregional input-output system. The key is the output difference between the case with and without that region in the system. These differences determine the degree of the importance of the extracted region by showing what would happen to the structure of the economy if the region disappeared from the system. The main underpinning concept may be traced to the interregional feedbacks introduced by Miller (1966). In general, the backward linkage is computed in terms of the Leontief inverse while the forward linkage is computed using the Ghoshian price model in the hypothetical extraction method. As proposed by Dietzenbacher *et al.* (1993), the output difference between the two cases - without and with a regional extraction - is calculated as follows:

$$x-\overline{x}=\begin{pmatrix} x^1-\overline{x}^1 \\ x^R-\overline{x}^R \end{pmatrix}=\left[\begin{pmatrix} L^{11} & L^{1R} \\ L^{R1} & L^{RR} \end{pmatrix}-\begin{pmatrix} (I-A^{11})^{-1} & 0 \\ 0 & (I-A^{RR})^{-1} \end{pmatrix}\right]\begin{pmatrix} f^1 \\ f^R \end{pmatrix} \quad (1)$$

where x denotes the output, L is the Leontief inverse matrix, A is the input coefficients matrix, and f is final demand vector. The superscript of 1 for the extracted region (element) and R for the rest of system are used, respectively. To measure the forward linkage, the difference is computed as follows:

$$(x-\overline{x})' = \left(v^{i}{}' \;\; v^{1}{}'\right)\left[\begin{pmatrix} G^{11} & G^{1R} \\ G^{R1} & G^{RR} \end{pmatrix} - \begin{pmatrix} (I-B^{11})^{-1} & 0 \\ 0 & (I-B^{RR})^{-1} \end{pmatrix}\right] \quad (2)$$

where v denotes the primary input vector, G is the Ghoshian inverse, $G=(I-B)^{-1}$, and B is the output coefficients matrix (output allocation matrix). The rest is as previously defined.

Dietzenbacher *et al.* (1997) combined both approaches of sectoral and regional extractions in the EC inter-country economic system to focus on the sectoral and spatial linkages at the same time. This approach enables us to find the answer to the question of what would happen to the structure of the economy if a specific economic sector in a specific region was removed from an interregional I-O framework. More detailed methodological explanation is found in section 3.

3. Combined hypothetical extraction methods

3.1. Data

This chapter conducts a series of hypothetical extraction methods for the U.S. interregional economy. The computations are carried out using the 2007 Midwest Interstate Social Account Matrix (2007 MW-MRSAM) constructed by the Regional Economics and Applications Laboratory (REAL) for the five Midwest states and the rest of U.S. (RUS, hereafter). The 2007 MW-MRSAM was built based on the method proposed by Jackson *et al.* (2006) using the 2007 IMPLAN data for Illinois, Indiana, Michigan, Ohio, Wisconsin, and the U.S. as a whole. In addition, the 2002 Commodity Flow Survey (CFS) data were used for the estimation of interstate flows; a Box-Cox regression was used for every sector. The 2007 MW-MRSAM contains the full set of interregional input-output information for 24 economic sectors: intermediate transaction flows, final demand categorized into household consumption, enterprise investment and government expenditure related components, foreign exports and imports, and value-added for each region. For the analysis in this chapter, the 24 economic sectors have been aggregated to 14 sectors. The description of each sector and the corresponding sectors defined in the 2007 MW-MRSAM are summarized in Table 4-1. Hence, the U.S. interregional input-output (IRIO) table covers six regions, each with 14 sectors. This IRIO table contains the full information on the origins and the destinations of the intermediate deliveries between sectors as well as regions.

Table 4-1. Sector classification for analysis in this study

Code	Sector description	2007 MW-MRSAM
1	Agriculture, Forestry and Fisheries	01
2	Mining (including Oil & Gas extraction)	02~04
3	Electricity, Natural Gas, Water, sewage and other systems	05~07
4	Construction	08
5	Food, Beverage, and Tobacco Product Manufacturing	09
6	Textile, Apparel, and Leather Product Manufacturing	10
7	Paper Manufacturing and Printing Related Activities	11
8	Chemical Products Manufacturing	12
9	Primary Metals and Metal Product Manufacturing	13
10	Machinery and Equipment Manufacturing	14
11	Wood, Furniture & Miscellaneous Manufacturing	15
12	Trade (including Transportation and Warehousing)	16~18
13	Finance, Insurance, and Management of companies/enterprises	19
14	Other Services (including Education and Health), and Government Enterprises	20~24

3.2. Methodology

The analyses in this chapter are divided into two main parts. The first part examines the regional economic interdependence focusing more on the sector linkages in an IRIO framework, while the second part focuses only on the spatial linkages among the six regions of study. Both of the parts are based on the equations (1) and (2). For the examination of spatial and sectoral linkages at the same time, this study replicates the method proposed by Dietzenbacher *et al.* (1997). A brief explanation of the approach follows; the analysis is based on the general case of an IRIO model with six regions (M=6) and 14 sectors (N=14). Define z_{ij}^{rs} as the intermediate deliveries from sector i in region r to sector j in region s. The interregional input coefficients are obtained as $a_{ij}^{rs} = z_{ij}^{rs} / x_j^s$, where x_j^s denotes the total output of sector j in region s. Then, this system can be written in a matrix terms as follows:

$$A = Z\hat{x}^{-1} \tag{3}$$

where $A = (14\times6)\times(14\times6)$-matrix of interregional input coefficients (a_{ij}^{rs})

$Z = (14\times6)\times(14\times6)$-matrix of intermediate deliveries among regions and sectors (z_{ij}^{rs})

$x = (14\times6)$-column vector of gross output per sector and per region (x_j^s)

The IRIO account equation is written as: $x = Ax + f$ (4)

where f is a (14×6)-column vector of final demand per sector and per region. Then, the solution of equation (4) will be: $x = (I - A)^{-1} f$ (5)

Now it is assumed that sector j in region r buys no intermediate inputs from any production sectors in the system. Based on this assumption, the input coefficients matrix is modified by substituting the column representing the sector j in region r with the column containing all zero cells. Define the newly yielded input coefficients matrix as $\overline{A}^{jr}$. Using the same final demand vector, solving this model yields the changed output level with the isolation of a buying sector j in region i, $\overline{x}^{jr} = (I - \overline{A}^{jr})^{-1} f$. Under the usual assumptions, the sectoral output decreases since sector j in region r depends no longer on the production sectors with regard to its input requirements in the system. The output decrease, $x - \overline{x}^{jr}$, is termed the absolute backward dependence of sector j, which means the dependence of sector j in region r on other sectors and on itself in the whole system. According to Dietzenbacher *et al.* (1997), this absolute backward dependence on other sectors comprises two parts: first, the output is reduced because other sectors no longer contribute to the final demand of sector j in region r. Second, in satisfying the final demand of other sectors, inputs from sector j in region r are required. In turn, these require inputs from other sectors, but these inputs have been omitted in the hypothetical case. In the same way, the absolute backward dependence of sector *j* upon itself has two parts, as well: the contribution to its own final demand of sector *j* and to the final demand in other sectors, which is reduced. For ease of interpretation, the results are normalized by dividing the absolute figures by the value of the output of sector *j* in region *r*.

To measure the forward linkages, the output coefficients matrix $B = \hat{x}^{-1}Z$ is needed. The output coefficients matrix is defined as $B = \left[b_{ij}^{rs} \right]$, where $b_{ij}^{rs} = z_{ij}^{rs} / x_i^r$. In a similar fashion as for the backward linkages, the absolute forward linkages are computed. For this hypothetical case, each element in row *j* in the output coefficients matrix *B* is set to zero and the new matrix is defined as $\overline{B}^{jr}$. Then, the weighted sums of the columns of the corresponding output inverse are obtained as $\overline{x}^{jr} = v(I - \overline{B}^{jr})^{-1}$. v denotes the (14×6)-row vector of primary inputs, that includes value added terms and foreign imports. The absolute forward linkages are also given by the vector of $x - \overline{x}^{jr}$. Its *i*th element describe the absolute forward dependence of sector *j* on sector *i*. According to the explanation of Dietzenbacher *et al.* (1997), the difference is due to the fact that sector *j* does not sell intermediate deliveries to sector *i*. Thus, the difference between the original output of sector *i* and the reduced output of sector *i* under the extraction hypothesis yields the seller's dependence upon sector *i* as a buyer. Similarly, relative forward linkages are obtained by measuring this seller's dependence as a percentage of the seller's output.

Based on the same logic, any extended extraction is possible. For instance, if any analysis is needed with the hypothesis that a specific sector is or a combination of several sectors are removed from the whole interregional economy system, the corresponding columns for the sector(s) are set to zeros in the input coefficients matrix to measure the backward linkages. The measure the forward linkages, the corresponding rows for the sector(s) in the output coefficients matrix are changed to zero.

4. Interregional economic interdependence

4.1. Regional extraction: *What if a region in the interregional economy system was isolated?*

What would happen to the economy of Illinois if Ohio stopped all production activities? What is the impact on the entire U.S. economy? The regional extraction method can examine how the isolation of one region from the whole regional economy will affect the production of the rest of the economy. Instead of extracting a sector in an interregional input-output system, a region will be hypothetically extracted and the impact on the remaining system of economies will be measured. This study conducts the regional extraction method approach in the six-region IRIO framework. All fourteen sectors are aggregated into one so as to focus only on the spatial linkages among the regions. Hence, the IRIO accounting table matrix is reduced to 6×6. For the backward linkages, all intermediate deliveries that a region buys are hypothetically extracted, and then the change of output levels is calculated. In order to calculate the forward linkages, all the intermediate deliveries that the region sells are hypothetically extracted. Technically, all cells of the corresponding column representing the region in the delivery inflows coefficient matrix is set to zero for the backward linkage calculation. When measuring the latter, all cells of the corresponding row indicating the region in the outflows coefficient matrix is set to zero.

The empirical results of the regional extraction method for the six-region U.S. economy are summarized in tables 4-2 and 4-3 after separate calculations of backward linkages and forward linkages. The elements in the upper parts of tables 4-2 and 4-3 are the output level changes for each affected region after each regional extraction. The lower parts of the tables report the spatial linkages in relative terms. The off-diagonal elements in the lower parts of the tables are given by dividing the corresponding absolute values by the actual output level of the isolated region. On the other hand, the diagonal elements in the lower parts of the tables are given by dividing the corresponding output level difference by the actual total output in the other regions excluding the isolated region. Then, the diagonal elements represent the backward (or forward) dependence of the other regions on input from the isolated region (or output of the isolated region). Each component is referred to as either the backward interregional feedbacks or the forward interregional feedbacks, respectively.

Table 4-2. Spatial backward linkage effects of regional extraction

	Isolated region					
Region affected	IL	IN	MI	OH	WI	RUS
	Absolute effect (in 2007 U.S. million dollars)					
IL	246536.36	22635.02	17641.84	16554.95	16288.02	192049.77
IN	16739.04	116415.73	13290.12	20610.53	4948.74	73731.67
MI	13653.14	11819.89	150180.08	29167.07	14469.73	96926.43
OH	12344.00	21909.35	31569.87	206996.37	5855.76	151900.68
WI	11682.46	3907.49	13941.60	4911.25	94445.89	68665.67
RUS	243883.02	125424.76	169624.29	251961.12	118527.72	843581.45
BIF	**246536.36**	116415.73	150180.08	206996.37	94445.89	***843581.45***
BL	298301.66	185696.52	246067.72	**323204.92**	160089.97	***583274.22***
BIF+BL	**544838.02**	302112.24	396247.81	530201.29	254535.85	***1426855.67***
X	1160354.31	532702.85	781130.24	931622.18	485819.14	21705375.87
	Relative effect					
IL	0.0101	0.0425	0.0226	0.0178	0.0335	0.0088
IN	0.0144	0.0046	0.0170	0.0221	0.0102	0.0034
MI	0.0118	0.0222	0.0061	0.0313	0.0298	0.0045
OH	0.0106	0.0411	0.0404	0.0084	0.0121	0.0070
WI	0.0101	0.0073	0.0178	0.0053	0.0038	0.0032
RUS	0.2102	0.2354	0.2172	0.2705	0.2440	0.2168
BIF	**0.0101**	0.0046	0.0061	0.0084	0.0038	***0.2168***
BL	0.2571	**0.3486**	0.3150	0.3469	0.3295	*0.0269*

Note 1: *BIF* is the backward interregional feedbacks which mean the backward dependence of the other regions on the isolated region (representing the diagonal element in each column).
Note 2: *BL* indicates the backward linkages of the isolated region with respect to the rest of the economy.
Note 3: *X* indicates the actual output level of each isolated region before the extraction.
Source: based on the regional extraction method with 6-region IRIO table for one aggregated sector

It is obvious that the RUS shows the largest absolute backward linkages to the other regions. This is because the RUS includes all the other 45 U.S. states while other five regions in this regional (geographical) frame represent an individual Midwest state respectively. It is also expected that the relative *BL* of the RUS would be much smaller than those for other five Midwest states since it was normalized relative to the (economic) size of the RUS. However, the *BIF* still should be much larger than those for the five Midwest states. Therefore, the interpretation is made based on a two-region scheme for the better understanding: among five Midwest states and the RUS. When examining the five Midwest states, Illinois, Ohio and Michigan have the highest absolute backward linkages while the absolute linkages of the Indiana and Wisconsin are smaller. Relative to the size of the economy in term of its total output, the Indiana and Wisconsin linkages become stronger. The backward linkage of Illinois with respect to other Midwest states appears smallest when normalizing the backward linkages by its economy size. However, the relative backward interregional feedbacks show that other regions within the Midwest depend on Illinois the most and then on Ohio in terms of backward linkages of production. Wisconsin shows the lowest backward interregional feedbacks.

For the forward linkages, the overall tendency is quite similar to the case of the backward linkages. For the Midwest regions, Illinois and Ohio have greater linkage effects while those of Wisconsin and Indiana are weaker. However, some detailed variations are observed. For the backward linkages with the respect to the other regions, Ohio has the largest linkages followed by Illinois. But for the forward linkages with the respect to the other regions, they trade the positions with each other, which means the Illinois shows the higher forward linkages to the other regions. Related to the forward interregional feedbacks, other regions within the Midwest have the most forward dependence on Ohio. In fact, Ohio shows the highest relative effects in both terms of *FIF* and *FL*. It is still true that Michigan takes the third place in the both absolute *FIF* and *FL*.

Table 4-3. Spatial forward linkage effects of regional extraction

	Isolated region					
Region affected	IL	IN	MI	OH	WI	RUS
	Absolute effect (in 2007 U.S. million dollars)					
IL	246842.41	16190.76	13788.20	12460.79	11237.16	210139.96
IN	23177.91	156046.79	12269.73	22733.47	3863.37	111085.32
MI	17326.06	12672.85	197287.45	31417.51	13220.38	144086.81
OH	16261.43	19656.65	29043.70	263611.97	4657.99	214064.48
WI	16792.51	4953.71	15122.92	6117.49	136284.51	105693.24
RUS	221345.27	82508.76	113247.02	177402.21	76413.70	623899.43
FIF	246842.41	156046.79	197287.45	**263611.97**	136284.51	***623899.43***
FL	**294903.18**	135982.74	183471.56	250131.47	109392.59	***785069.81***
FIF+FL	**541745.58**	292029.53	380759.02	513743.44	245677.09	1408969.24
X	1160354.31	532702.85	781130.24	931622.18	485819.14	21705375.87
	Relative effect					
IL	0.0101	0.0304	0.0177	0.0134	0.0231	0.0097
IN	0.0200	0.0062	0.0157	0.0244	0.0080	0.0051
MI	0.0149	0.0238	0.0080	0.0337	0.0272	0.0066
OH	0.0140	0.0369	0.0372	0.0107	0.0096	0.0099
WI	0.0145	0.0093	0.0194	0.0066	0.0054	0.0049
RUS	0.1908	0.1549	0.1450	0.1904	0.1573	0.1603
FIF	0.0101	0.0062	0.0080	**0.0107**	0.0054	***0.1603***
FL	0.2541	0.2553	0.2349	**0.2685**	0.2252	*0.0362*

Note 1: *FL* indicates the forward linkages of the isolated region with respect to the rest of the economy (calculated as the sum of the off-diagonal elements in each column).
Note 2: *FIF* is the forward interregional feedbacks which mean the forward dependence of the other regions on the isolated region (representing the diagonal element in each column).
Note 3: *X* indicates the actual output level of each isolated region before the extraction.
Source: based on the regional extraction method with 6-region IRIO table for one aggregated sector

Note that all four Midwest states except Illinois have higher relative *BL* than *FL*. This finding means that they are more dependent on other regions in the U.S. as a buyer of their inputs rather than as a seller of their outputs. On the other hand, the relative forward interregional feedbacks of these four states are larger than the relative backward interregional feedbacks implying that the forward dependence of other regions in the U.S. on one of these four states is stronger than other regions' backward dependence on the single state. It implies that other regions in the U.S. depend on the state as a market for their products. In sum, Illinois and

Ohio behave as the most significant markets for the sales of other Midwest states. Besides, they are also important source of inputs for the production in other states within the Midwest.

4.2. Sectoral extraction: *What if a sector was removed from the economy system?*

In order to focus on the sectoral linkages, a second set of extractions is conducted with the hypothesis of the removal of a specific sector from the U.S. interregional economy. First, both backward and forward linkages of the removed sector toward the entire U.S. economy system are computed and reported in tables 4-4 and 4-5. The upper parts of the two tables summarize the absolute linkage effects and the lower parts of them report the relative effects. The separate interpretation should be made for the diagonal elements and the off-diagonal elements in the lower part of the tables. The same logic should be used in interpreting the results from the regional extraction above.

The off-diagonal elements indicate the backward and forward linkages of the extracted sector with respect to the other sectors in the system, respectively. The diagonal elements indicate the backward dependence of the rest of sectors upon the extracted sector or the forward dependence of other sectors on the extracted one. These are termed the backward inter-sectoral feedback (*BIF*) and the forward inter-sectoral feedback (*FIF*) as done in the regional extraction analyses.

Table 4-4. Sectoral backward linkages in the U.S., 2007

Sector affected	Extracted sector 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Absolute effect (in 2007 U.S. million dollars)													
1	244216.26	315490.34	262994.06	160907.88	159223.32	27558.93	171255.12	855467.42	513701.96	277385.64	127081.40	1002959.4	1414464.2	2204123.1
2	7908.70	1717.41	491.56	10921.77	193789.62	1552.57	10139.24	7472.73	996.37	3050.88	23502.20	7023.99	3124.90	46087.12
3	8237.11	13963.82	58669.25	49577.09	15856.44	5002.97	6965.11	216143.60	17440.20	25663.23	6712.37	31064.95	5661.23	63577.08
4	2955.12	22490.42	11446.27	26578.60	27112.82	4708.64	13545.22	55707.36	23264.71	30004.91	7635.17	44753.35	13435.93	115591.93
5	22894.81	1418.63	692.76	6868.83	7925.95	1301.32	3595.18	21939.92	7135.27	12551.13	3395.57	26291.30	13654.24	94416.92
6	611.29	381.38	190.93	4813.90	1621.50	1779.93	2580.73	9038.26	1689.53	4517.54	2537.76	11791.97	7096.13	130765.72
7	2633.18	3305.04	1201.61	14512.00	37889.98	1943.83	2116.31	4091.10	541.42	5233.25	3613.10	5794.15	669.11	8498.23
8	45381.85	31730.01	13223.03	238019.50	79118.28	31232.97	31204.22	21259.66	5798.69	16712.57	5709.97	25401.50	15742.72	80816.54
9	3810.60	22790.86	5266.25	130413.16	36570.10	3295.81	7703.59	39964.19	33622.79	121548.09	37578.00	162576.25	23081.70	273415.89
10	4278.28	13938.00	5773.56	81308.22	15090.84	2563.34	6979.76	29929.61	25549.44	245972.72	26379.23	36946.20	7686.11	85558.99
11	1196.85	2085.80	955.02	60933.22	3017.04	800.23	3874.84	6053.87	2307.32	11122.77	10337.66	47972.30	12533.92	115506.67
12	26664.40	29170.16	38581.06	226035.53	116259.72	17719.30	37774.62	145473.98	67746.29	188807.56	42326.96	11433.82	3894.43	50921.69
13	25324.10	51952.00	19236.39	119777.52	95179.19	13064.46	23915.02	151456.74	50819.32	174758.20	31208.35	282392.21	45108.54	363950.18
14	68928.28	98190.31	49858.33	416363.52	157053.08	29953.46	53035.24	258834.18	122112.38	306364.55	74141.19	754032.92	587336.70	833145.18
X	371403.18	491981.33	468046.23	1606362.1	843767.96	139329.16	282248.73	1748812.4	667750.37	1701975.1	358770.25	3370470.6	2464618.3	11081468.
BIF	244216.26	315490.34	262994.06	160907.88	159223.32	27558.93	171255.12	855467.42	513701.96	277385.64	127081.40	1002959.4	1414464.2	2204123.1
BL	220824.57	293133.86	205586.02	1386122.8	786484.55	114918.84	203429.12	967365.21	359023.74	1146307.4	275077.53	1447474.9	739025.66	2262252.1
BIF+BL	465040.83	608624.19	468580.08	1547030.7	945707.87	142477.77	374684.24	1822832.6	872725.70	1423693.0	402158.92	2450434.3	2153489.9	4466375.2
	Relative effect													
1	0.0097	0.0059	0.0024	0.0079	0.2464	0.0135	0.0498	0.0077	0.0028	0.0027	0.0854	0.0049	0.0042	0.0204
2	0.0358	0.0126	0.2854	0.0358	0.0202	0.0435	0.0342	0.2234	0.0486	0.0224	0.0244	0.0215	0.0077	0.0281
3	0.0373	0.0476	0.0105	0.0192	0.0345	0.0410	0.0666	0.0576	0.0648	0.0262	0.0278	0.0309	0.0182	0.0511
4	0.0134	0.0767	0.0557	0.0067	0.0101	0.0113	0.0177	0.0227	0.0199	0.0109	0.0123	0.0182	0.0185	0.0417
5	0.1037	0.0048	0.0034	0.0050	0.0064	0.0155	0.0127	0.0093	0.0047	0.0039	0.0092	0.0081	0.0096	0.0578
6	0.0028	0.0013	0.0009	0.0035	0.0021	0.0011	0.0104	0.0042	0.0015	0.0046	0.0131	0.0040	0.0009	0.0038
7	0.0119	0.0113	0.0058	0.0105	0.0482	0.0169	0.0068	0.0220	0.0162	0.0146	0.0208	0.0175	0.0213	0.0357
8	0.2055	0.1082	0.0643	0.1717	0.1006	0.2718	0.1534	0.0359	0.0937	0.1060	0.1366	0.1123	0.0312	0.1209
9	0.0173	0.0777	0.0256	0.0941	0.0465	0.0287	0.0379	0.0413	0.0206	0.2146	0.0959	0.0255	0.0104	0.0378
10	0.0194	0.0475	0.0281	0.0587	0.0192	0.0223	0.0343	0.0309	0.0712	0.0116	0.0376	0.0331	0.0170	0.0511
11	0.0054	0.0071	0.0046	0.0440	0.0038	0.0070	0.0190	0.0063	0.0064	0.0097	0.0050	0.0079	0.0053	0.0225
12	0.1207	0.0995	0.1877	0.1631	0.1478	0.1542	0.1857	0.1504	0.1887	0.1647	0.1539	0.0451	0.0610	0.1609
13	0.1147	0.1772	0.0936	0.0864	0.1210	0.1137	0.1176	0.1566	0.1415	0.1525	0.1135	0.1951	0.0611	0.3683
14	0.3121	0.3350	0.2425	0.3004	0.1997	0.2606	0.2607	0.2676	0.3401	0.2673	0.2695	0.5209	0.7947	0.1518
BIF	0.0097	0.0126	0.0105	0.0067	0.0064	0.0011	0.0068	0.0359	0.0206	0.0116	0.0050	0.0451	0.0611	**0.1518**
BL	0.5946	0.5958	0.4392	0.8629	**0.9321**	0.8248	0.7207	0.5532	0.5377	0.6735	0.7667	0.4295	0.2999	0.2041

Note 1: *BIF* is the backward inter-sectoral feedbacks which mean the backward dependence of the other sectors on the extracted sector (representing the diagonal element in each column).

Note 2: *BL* indicates the backward linkages of the extracted sector with respect to the rest of sectors.

Note 3: *X* indicates the actual output level of each extracted sector before the extraction.

Source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 disaggregated sectors.

Table 4-5. Sectoral forward linkages in the U.S., 2007

Sector affected	Extracted sector 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Absolute effect (in 2007 U.S. million dollars)													
1	151856.10	182901.33	125056.42	791565.45	558432.93	73208.53	146230.55	773623.85	299014.83	783770.01	168928.92	984379.25	675560.90	1826948.40
2	1479.85	9092.92	9991.69	3577.69	21818.53	656.02	2592.74	42665.59	3386.68	4292.85	1330.02	29632.57	23092.26	66278.82
3	401.65	55479.46	14691.31	23616.55	1172.60	354.99	2822.59	25873.66	17568.47	12130.25	2010.41	28116.96	41089.12	81891.34
4	8930.50	46914.80	26535.50	11397.64	542.99	168.53	973.12	10224.70	3849.52	4764.80	872.88	35264.31	14427.12	39431.09
5	200437.44	18980.16	34240.13	9990.21	5387.69	4252.06	11760.80	184178.53	95396.74	67149.44	55731.96	206749.80	89895.66	329519.33
6	1427.85	5324.83	5287.36	1458.45	1570.25	1811.69	38841.84	77440.63	33837.94	15764.74	3490.57	134512.68	90358.91	157224.51
7	10180.64	8093.64	16606.12	4399.12	2485.70	2295.46	1771.80	27182.43	2711.59	2381.02	823.21	18229.03	11028.17	26662.68
8	7863.41	263220.62	71574.18	28134.66	9123.32	4650.41	22172.51	29650.14	6919.78	7078.41	4352.03	42428.28	22040.48	51541.81
9	1103.89	22361.62	31471.37	9633.65	1795.60	647.98	6367.40	35251.95	37621.14	31809.57	7125.78	171238.91	146285.31	263620.12
10	3002.56	29229.74	36055.56	15053.09	4264.88	5563.64	16301.89	113203.37	216562.78	28589.88	2859.44	83960.84	51679.12	130945.55
11	20915.37	6913.20	8296.37	3682.52	2166.42	3473.42	5036.37	31647.14	21001.41	9291.90	12244.69	207860.77	157864.95	291831.04
12	6261.62	32049.37	48712.54	28562.09	10083.83	5579.72	22443.43	137152.48	29464.70	43193.52	11401.49	42136.63	25492.27	63861.94
13	3394.63	7117.26	17821.16	18075.85	7394.59	785.19	16949.73	23728.35	7469.51	13752.07	4732.24	54815.12	231066.09	650606.83
14	47499.07	75831.94	145460.61	118585.19	129281.38	9461.36	82553.00	266669.29	78886.11	120236.91	58705.09	419597.72	788146.38	617545.00
X	371403.18	491981.33	468046.23	1606362.15	843767.96	139329.16	282248.73	1748812.42	667750.37	1701975.16	358770.25	3370470.64	2464618.31	11081468.72
FIF	151856.10	182901.33	125056.42	791565.45	558432.93	73208.53	146230.55	773623.85	299014.83	783770.01	168928.92	984379.25	675560.90	1826948.40
FL	312898.49	580609.55	466743.90	276166.70	197087.78	39700.47	230587.23	1004868.24	554676.38	360435.37	165679.80	1474543.62	1692465.86	2770960.06
FIF+FL	464754.59	763510.88	591800.32	1067732.14	755520.71	112909.00	376817.78	1778492.09	853691.21	1144205.38	334608.72	2458922.87	2368026.76	4597908.45
	Relative effect													
1	0.0060	0.0157	0.0214	0.0130	0.1107	0.0165	0.0112	0.0425	0.0061	0.0119	0.0080	0.0201	0.0136	0.0239
2	0.0047	0.0073	0.0315	0.0855	0.0059	0.0089	0.0122	0.0257	0.0317	0.0337	0.0121	0.0191	0.0243	0.0296
3	0.0013	0.0956	0.0050	0.0413	0.0028	0.0042	0.0042	0.0102	0.0069	0.0132	0.0053	0.0239	0.0085	0.0142
4	0.0285	0.0808	0.0569	0.0330	0.0273	0.1071	0.0510	0.1833	0.1720	0.1863	0.3364	0.1402	0.0531	0.1189
5	0.6406	0.0327	0.0734	0.0362	0.0226	0.0456	0.1684	0.0771	0.0610	0.0437	0.0211	0.0912	0.0534	0.0567
6	0.0046	0.0092	0.0113	0.0053	0.0080	0.0029	0.0077	0.0271	0.0049	0.0066	0.0050	0.0124	0.0065	0.0096
7	0.0325	0.0139	0.0356	0.0159	0.0126	0.0578	0.0058	0.0295	0.0125	0.0196	0.0263	0.0288	0.0130	0.0186
8	0.0251	0.4534	0.1533	0.1019	0.0463	0.1171	0.0962	0.0324	0.0678	0.0883	0.0430	0.1161	0.0864	0.0951
9	0.0035	0.0385	0.0674	0.0349	0.0091	0.0163	0.0276	0.0351	0.0120	0.0793	0.0173	0.0569	0.0305	0.0473
10	0.0096	0.0503	0.0772	0.0545	0.0216	0.1401	0.0707	0.1127	0.3904	0.0328	0.0739	0.1410	0.0933	0.1053
11	0.0668	0.0119	0.0178	0.0133	0.0110	0.0875	0.0218	0.0315	0.0379	0.0258	0.0067	0.0286	0.0151	0.0230
12	0.0200	0.0552	0.1044	0.1034	0.0512	0.1405	0.0973	0.1365	0.0531	0.1198	0.0688	0.0443	0.1365	0.2348
13	0.0108	0.0123	0.0382	0.0655	0.0375	0.0198	0.0735	0.0236	0.0135	0.0382	0.0286	0.0372	0.0292	0.2229
14	0.1518	0.1306	0.3116	0.4294	0.6560	0.2383	0.3580	0.2654	0.1422	0.3336	0.3543	0.2846	0.4657	0.1259
FIF	0.0060	0.0073	0.0050	0.0330	0.0226	0.0029	0.0058	0.0324	0.0120	0.0328	0.0067	0.0443	0.0292	**0.1259**
FL	0.8425	**1.1801**	0.9972	0.1719	0.2336	0.2849	0.8170	0.5746	0.8307	0.2118	0.4618	0.4375	0.6867	0.2501

Note 1: *FIF* is the forward inter-sectoral feedbacks which mean the backward dependence of the other sectors on the extracted sector (representing the diagonal element in each column).
Note 2: *FL* indicates the forward linkages of the extracted sector with respect to the rest of sectors.
Note 3: *X* indicates the actual output level of each extracted sector before the extraction.
Source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 disaggregated sectors

Sector 5 has the greatest backward linkages with respect to other sectors, while sector 2 has the greatest forward linkages to the other sectors in the economy. For the backward linkages to other sectors, sector 4, 6, 11, and 7 also have significant backward linkage effects. Intuitively, one can understand that consumption goods such as food, beverage, tobacco, textile, apparel, leather, wood and furniture, and paper would have larger backward linkage effects. Besides, it could also be expected that the construction would show stronger backward linkages. On the other hand, all services and energy sectors have weaker backward linkages. These sectors do not have stronger forward linkages either since a large part of the outputs from such sectors is usually destined for final demand purposes. Sectors that are generally fed into another production process as inputs show high forward linkages to other sectors such as sectors 2, 3, 9, 7, and 13. Based on the same logic, it is also understood that consumption goods (in sectors 5 and 6 mainly) and construction (sector 4) show lower forward linkages to other sectors in the U.S economy.

4.3. Spatial and sectoral production linkages: *What if Illinois stopped production in a specific sector?*

This section examines the spatial effect of Illinois on the U.S. regional economies. In addition, the analysis provides more details of the sectoral linkages of Illinois. The objective is to find the answers to questions such as "what would happen if Illinois shuts down its all chemical products production process, on Illinois itself, the entire U.S, to the Midwest area covering five states of this study, and to each individual Midwest state?" In order to identify the spatial and sectoral production linkages of Illinois, the combined spatial and sectoral extraction methods are employed.

Tables 4-6 and 4-7 compare the total output changes in three different geographical schemes, the U.S., the Midwest, and Illinois itself, with the extraction hypothesis for a sector of Illinois. The values in the tables are shown in relative terms representing the influence of the extraction of a sector of Illinois within the region of interest. The sector of each column represents the sector hypothetically removed from Illinois. Table 4-6 is for total backward linkages and Table 4-7 is for the total forward linkages. For example, if sector 01 is removed from Illinois, the total U.S. output would decrease by around 0.08% of its current total output level (when no hypothetical extractions exist) due to the backward linkages effect the sector in Illinois has. For the same sector 01, the backward linkage effect would decrease the total output level of the Midwest area would by 0.33%. For Illinois itself, the backward linkage effects would decrease production by 0.84%.

Table 4-6. Total backward linkage effects of each sector in Illinois

Region Affected	Extracted sector from Illinois 1	2	3	4	5	6	7	8	9	10	11	12	13	14
U.S.[1)]	0.00075	0.00067	0.00082	0.00260	0.00317	0.00013	0.00100	0.00386	0.00325	0.00299	0.00061	0.00535	0.00585	**0.01136**
Ranking	11	12	10	8	6	14	9	4	5	7	13	3	2	**1**
Midwest[2)]	0.00331	0.00361	0.00421	0.01143	0.01132	0.00052	0.00462	0.01819	0.01495	0.01180	0.00270	0.02705	0.03014	**0.05376**
Ranking	12	11	10	7	8	14	9	4	5	6	13	3	2	**1**
Illinois[2)]	0.01022	0.01157	0.01363	0.03353	0.03041	0.00158	0.01362	0.05728	0.04320	0.03039	0.00806	0.08555	0.09682	**0.16693**
Ranking	12	11	9	6	7	14	10	4	5	8	13	3	2	**1**

1) relative values calculated by dividing total backward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total U.S. output
2) relative values calculated by dividing total backward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total Midwest output
3) relative values calculated by dividing total backward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total Illinois output
Note: Rankings are determined within the same row so as to compare the significance between sectors in Illinois.
Data source: 1992 and 2007 MWREIM

The rankings indicate which sector would have greater significance in each economic system. The structures are almost identical with some trivial variations among regions. According to table 4-6, sector 14 of Illinois has the most significant backward linkage effects, while sector 6 has the weakest effects on all three regional economies. It might imply that sector 14 in Illinois is the most important buyer in the interregional production structure. Essentially, it means other sectors and regions in the economy are affected the most if sector 14 of Illinois stopped production, since other sectors would lose a large market for the sale of their outputs within the regional economy. Related to the strong impact of sector 14 in Illinois, previous studies on the economy of Illinois (centered by the Chicago Metropolitan Area) already showed that the service sectors have surpassed other sectors, particularly manufacturing sectors, in terms of their analytical importance in the last two decades (Hewings *et al.*, 1996; 1998).

Table 4-7. Total forward linkage effects of each sector in Illinois

Region affected	Extracted sector from Illinois													
	1	2	3	4	5	6	7	8	9	10	11	12	13	**14**
U.S.[1)]	0.00069	0.00090	0.00102	0.00174	0.00231	0.00009	0.00102	0.00369	0.00346	0.00225	0.00050	0.00540	0.00687	**0.01188**
Ranking	12	11	10	8	6	14	9	4	5	7	13	3	2	**1**
Midwest[2)]	0.00307	0.00501	0.00529	0.01097	0.01220	0.00048	0.00336	0.02189	0.01067	0.01395	0.00288	0.02833	0.02817	**0.05557**
Ranking	12	10	9	7	6	14	11	4	8	5	13	2	3	**1**
Illinois[2)]	0.00842	0.01556	0.01623	0.03622	0.03699	0.00139	0.00802	0.06893	0.02383	0.04585	0.00915	0.08644	0.07821	**0.16129**
Ranking	12	10	9	7	6	14	13	4	8	5	11	2	3	**1**

1) relative values calculated by dividing total forward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total U.S. output.
2) relative values calculated by dividing total forward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total Midwest output.
3) relative values calculated by dividing total forward linkage effects (the output changes due to the extraction of the sector in the corresponding column) by the total Illinois output
Note: Rankings are determined within the same row so as to compare the significance between sectors in Illinois.
Data source: 1992 and 2007 MWREIM

The forward linkage effects of the sectors of Illinois also seem to have a very similar tendency as backward linkages in terms of their effects on each region. However, some differences are observed within the Midwest and Illinois from those in the U.S. Sector 9 of Illinois has a weaker impact in the Midwest and Illinois economy compared to the U.S. Comparing entries in tables 4-6 and 4-7, sector 9 in Illinois has more significance as a buyer of products from other regions and other sectors within the production system of the Midwest and Illinois itself.

In summary, at the sectoral level, the average production structures in three different regional economic systems exhibit general similarities. This outcome might be because this analysis focused on the impact of Illinois' production structure. Illinois is one of the more typical economic entities in the U.S. economy as well as in the Midwest. For this reason, spatial considerations rather than the technological factors should be more important in the interregional economy context.

Tables 4-8 and 4-9 show the more detailed spatial backward and forward linkages of each sector of Illinois. The values in the upper parts of the tables are normalized by the total output change with the extraction of the corresponding sector. The lower parts of the tables report the rankings within the same column so as to identify which region is more affected by the removal of the sector from Illinois.

Table 4-8. Backward linkages of each sector in Illinois to other regions

	Sector extracted from Illinois													
Region affected	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Illinois	0.96121	1.19334	0.83826	0.61617	0.70155	0.83258	1.15679	0.79867	1.19839	0.47981	0.69022	0.60822	0.81793	0.40700
Indiana	0.03404	0.01615	0.01062	0.03084	0.05842	0.02715	0.03675	0.01941	0.06943	0.04427	0.03196	0.01025	0.00690	0.00827
Michigan	0.01646	0.01474	0.00758	0.02039	0.03183	0.01710	0.02990	0.01037	0.04005	0.04251	0.01682	0.01042	0.01045	0.00929
Ohio	0.01605	0.01503	0.00716	0.02163	0.03271	0.02471	0.03317	0.01363	0.04911	0.03769	0.01879	0.00900	0.00879	0.00740
Wisconsin	0.01516	0.01046	0.00513	0.01555	0.05138	0.01553	0.05882	0.00870	0.03374	0.02059	0.01778	0.00716	0.00992	0.00768
RUS	0.50783	0.26571	0.24637	0.34858	0.73578	0.53884	0.55133	0.33776	0.59726	0.41526	0.38573	0.19388	0.23634	0.17156
	Rankings of spatial backward linkage effects (ranked within the same column)													
Illinois	1	1	1	1	2	1	1	1	1	1	1	1	1	1
Indiana	3	3	3	3	3	3	4	3	3	3	3	4	6	4
Michigan	4	5	4	5	6	5	6	5	5	4	6	3	3	3
Ohio	5	4	5	4	5	4	5	4	4	5	4	5	5	6
Wisconsin	6	6	6	6	4	6	3	6	6	6	5	6	4	5
RUS	2	2	2	2	1	2	2	2	2	2	2	2	2	2

Source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 disaggregated sectors.

Table 4-9. Forward linkages of each sector in Illinois to other regions

	Sector extracted from Illinois													
Region affected	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Illinois	0.79149	1.60431	0.99844	0.66560	0.85334	0.73385	0.68082	0.96116	0.66103	0.72383	0.78370	0.61454	0.66065	0.39326
Indiana	0.07078	0.04303	0.02591	0.00316	0.03165	0.02610	0.06437	0.01802	0.10598	0.00449	0.01287	0.01575	0.04464	0.01908
Michigan	0.03233	0.02929	0.01741	0.00242	0.01998	0.02669	0.05539	0.01515	0.07858	0.00347	0.00944	0.01565	0.03243	0.01527
Ohio	0.03493	0.02636	0.02391	0.00230	0.01887	0.03042	0.06549	0.01269	0.07985	0.00342	0.00982	0.01850	0.02840	0.01312
Wisconsin	0.03768	0.02916	0.02564	0.00232	0.02012	0.02244	0.08983	0.01666	0.06774	0.00319	0.01160	0.01095	0.03206	0.01369
RUS	0.45776	0.32649	0.28902	0.03058	0.23078	0.19736	0.96329	0.11136	1.12612	0.04528	0.11541	0.17120	0.48271	0.18469
	Rankings of spatial forward linkage effects (ranked within the same column)													
Illinois	1	1	1	1	1	1	2	1	2	1	1	1	1	1
Indiana	3	3	3	3	3	5	5	3	3	3	3	4	3	3
Michigan	6	4	6	4	5	4	6	5	5	4	6	5	4	4
Ohio	5	6	5	6	6	3	4	6	4	5	5	3	6	6
Wisconsin	4	5	4	5	4	6	3	4	6	6	4	6	5	5
RUS	2	2	2	2	2	2	1	2	1	2	2	2	2	2

Source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 disaggregated sectors.

As expected, the self-dependence of Illinois generates the more important impacts. The RUS takes the second position in both backward and forward spatial linkages. Three exceptions are observed. Sector 5 of Illinois has the strongest backward spatial linkage with the RUS and the sectors 7 and 9 of Illinois have the strongest forward linkages with the RUS. It might tell us that sector 5 of Illinois is one of the major buyers in the market of the RUS and the sectors 7 and 9 of Illinois are significant sources of the production in the RUS.

Generally speaking, Illinois has the strongest spatial linkage with Indiana within the Midwest. The linkages with Michigan, Ohio, and Wisconsin are more moderate and variable. For sector 6, Illinois has larger forward spatial linkages to Ohio, followed by Michigan. However, the spatial linkage to Indiana is relatively smaller than for the other sectors. For sector 7, Wisconsin shows greater spatial linkages with Illinois from both the backward and forward perspectives. Of note is that sector 12 in Illinois has quite strong spatial forward linkages with Ohio. It displays the significance of the trade sector of Illinois as a provider to Ohio that in turn might be related to the quite strong interstate trade partnership between Illinois and Ohio. Note also that the service sectors (sector 12~14) of Illinois have stronger backward spatial linkages with Michigan. As already mentioned, Indiana usually takes the third place in the spatial backward linkages with Illinois. However, Michigan replaces Indiana in this case. It might imply that service sectors of Illinois have a larger influence on the regional economy of Michigan. In general, the spatial linkages between Illinois and Wisconsin are the weakest within the Midwest.

The absolute output changes due to the hypothetical extraction of each sector of Illinois are normalized to relative values based on the size of the total sum of output changes. Based on the relative effects, the first 15 highest backward and forward spatial and sectoral linkages are identified in tables 4-10 and 4-11, respectively. These two tables show more detailed interregional and intersectoral linkages of each sector of Illinois, and the overall trend is consistent with the patterns detected in the tables 4-8 and 4-9 displaying the average spatial linkages above.

Table 4-10. Top 15 pairs of region and sector with high total backward linkages

	Extracted sector from Illinois													
Rankings	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	I01	I02	I03	I14	I05	I06	I07	I08	I09	I10	I11	I12	I13	I14
2	R01	I14	R02	I08	R01	I08	R07	R02	R09	R09	I14	I14	I14	R14
3	I08	R14	I02	I12	R14	R06	R14	I14	R14	I14	R14	R14	R13	I13
4	I14	I04	I12	I04	I12	I14	I12	I02	I14	R14	I12	I08	R14	R13
5	R14	I13	I14	R14	R05	R14	I14	R14	I12	I12	I08	I13	I12	I12
6	I12	R02	R14	R09	I14	I12	I08	I12	R13	R10	R09	R13	R12	I08
7	R08	I08	R13	I10	R13	R08	R13	R08	I08	I08	R01	R12	I08	R12
8	R13	R13	R12	R13	I08	R13	R08	R13	R12	R13	R13	R08	W13	I10
9	I13	I12	I08	I13	I13	I13	R12	I13	J09	I13	R11	I10	R07	R08
10	I05	R09	I04	R08	R08	R12	I13	I03	I13	R12	I13	R09	M14	I04
11	R05	I03	I13	R12	R12	R02	W07	R12	I10	R08	R08	I03	R08	I03
12	R12	I10	R08	R02	I01	I03	R01	R09	R02	M10	R12	R02	I04	R09
13	R02	R12	R09	I11	R07	R09	I03	I10	O09	J09	I10	I04	O13	I05
14	I03	R08	I10	R10	R09	I02	R02	R03	R08	R02	R02	R10	I10	R07
15	J01	R10	R10	R11	W05	R03	R09	I04	I03	O09	R10	R07	M13	R02

Note: The first capital letter indicates the region affected and the last two-digit number indicates the sector affected.
I-Illinois / J-Indiana / M-Michigan / O-Ohio / W-Wisconsin / R-RUS
Data source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 sectors

Table 4-11. Top 15 pairs of region and sector with high total forward linkages

	Extracted sector from Illinois													
Rankings	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	I01	I08	I03	I04	I05	I06	I07	I08	I09	I10	I11	I12	I13	I14
2	R05	I02	I14	I14	R05	R06	R14	I14	R10	I14	I14	I14	R14	R14
3	I05	I14	I08	I12	R14	R14	R07	I12	R09	I04	I04	R14	I14	I13
4	R01	I03	R14	I08	I14	I14	R05	I04	R04	I12	R14	I10	R13	I12
5	R14	I12	I12	I13	J05	R10	R12	I10	R14	I09	I12	I04	I12	R13
6	J05	I04	I05	I02	R01	R12	R08	I05	R08	I08	R04	I08	R12	R12
7	W05	R14	I09	R14	W05	I08	R13	R14	R05	R14	I10	I05	R10	I04
8	R11	R08	I10	I10	J14	I12	R10	I09	R12	R10	I08	R12	R08	I08
9	I14	I10	R10	I03	O05	R04	W07	I01	J09	I05	R11	I09	I08	I10
10	O05	R04	I04	I05	M05	I10	R04	R05	M10	I13	R10	R10	I10	R10
11	M05	R09	I13	I09	M14	R08	I14	I07	J10	R09	I13	R05	R05	R04
12	J01	I05	R12	R10	I01	R11	R09	R08	R11	R04	R12	R08	R04	R08
13	R07	R10	R09	R13	R12	I04	R11	R10	R02	R05	I07	R04	I05	I05
14	R04	I09	R05	R12	O14	R07	O14	I11	O10	R12	R13	R09	I04	I09
15	I11	R03	R08	R04	R13	M10	W05	R04	O09	I11	I05	I13	R09	R05

Note: The first capital letter indicates the region affected and the last two-digit number indicates the sector affected.
I-Illinois, J-Indiana, M-Michigan, O-Ohio, W-Wisconsin, R-RUS
Data source: based on the hypothetical sectoral extraction method with 6-region IRIO table for 14 sectors

5. Conclusion

This chapter employed the hypothetical extraction methods to explore the interregional and intersectoral interdependence in the U.S. The analysis was conducted using the interregional I-O system that covers five Midwest states and the RUS. Since the IRIO is built with more detail for the Midwest, the detailed analysis focuses on these Midwest states.

A hypothetical regional extraction reveals that Illinois and Ohio are the most significant markets for the sales made from the other Midwest states. At the same time, they are also important sources of inputs for the production in other states within the Midwest. Hence, the spatial linkages within the Midwest can be portrayed as: Illinois and Ohio produce the strongest regional economic linkages and Indiana and Michigan, and Wisconsin show the second-level dependence with Illinois and Ohio, respectively.

When the interregional and intersectoral interdependence of the Illinois economy is examined as an example, the services sector of Illinois has the most significant linkages with other sectors and other regions in the entire regional economic system. For the spatial linkages, the strongest linkage exists with the RUS. The second level of spatial linkage is found to be with Indiana, and the third level of spatial linkages could be defined with other three Midwest states of Michigan, Ohio, and Wisconsin.

Identifying which industries in one region have the strongest and the closest relationship with other industries in another region is very useful for policy makers. Based on the results of the analyses in this chapter, a set of tables can be presented. The following two tables contain three sets of information. The first set is the absolute linkage effects represented by the total output changes when the corresponding sector (indicated by each column) was removed from a specific region (indicated by each row). The second set (in the middle part of the tables) displays the relative effects by normalizing the total output changes shown in the first part of tables based on the U.S. total output change when the corresponding sector is removed from the entire U.S. economy system. The last set (in the last part of the tables) shows how much percentage of the U.S. total output each sector in each region absorbs.

Table 4-12. Total backward linkages for each extraction hypothesis

	Extracted sector													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
From	Absolute effects (in 2007 U.S. million dollars)													
US	465041	608624	468580	1547031	945708	142478	374684	1822833	872726	1423693	402159	2450434	2153490	4466375
IL	19136	17052	21036	66503	81059	3207	25509	98902	83151	76453	15741	136929	149768	290874
IN	13606	5223	10126	36006	31962	1955	12119	63272	94277	95073	19199	59167	38816	102620
MI	10527	6750	18175	45123	32917	1972	16528	57468	61780	163563	13817	78337	68580	178902
OH	12470	9594	15142	58407	50241	4286	25688	98922	118676	135735	15724	107572	103324	202320
WI	16449	1404	7029	31632	506670	2507	43051	36834	48340	62423	14754	53053	54279	97241
RUS	407932	570975	397082	1302678	787935	133785	305282	1514612	673975	1082913	331961	2068216	1880930	3949647
	Relative effects (%, relative to the size of total backward linkages with the removal of the corresponding sector from the entire U.S.)													
IL	4.11%	2.80%	4.49%	4.30%	**8.57%**	2.25%	6.81%	5.43%	**9.53%**	5.37%	3.91%	5.59%	**6.95%**	6.51%
IN	2.93%	0.86%	2.16%	2.33%	3.38%	1.37%	3.23%	3.47%	**10.80%**	6.68%	4.77%	2.41%	1.80%	2.30%
MI	2.26%	1.11%	3.88%	2.92%	3.48%	1.38%	4.41%	3.15%	**7.08%**	**11.49%**	3.44%	3.20%	3.18%	4.01%
OH	2.68%	1.58%	3.23%	3.78%	5.31%	3.01%	**6.86%**	5.43%	**13.60%**	**9.53%**	3.91%	4.39%	4.80%	4.53%
WI	3.54%	0.23%	1.50%	2.04%	5.36%	1.76%	**11.49%**	2.02%	5.54%	4.38%	3.67%	2.17%	2.52%	2.18%
RUS	87.72%	93.81%	84.74%	84.21%	83.32%	93.90%	81.48%	83.09%	77.23%	76.06%	82.54%	84.40%	87.34%	88.43%
	Percentage of the output composition													
IL	0.05%	0.04%	0.07%	0.25%	0.20%	0.01%	0.05%	0.33%	0.16%	0.29%	0.05%	**0.64%**	**0.54%**	**1.86%**
IN	0.03%	0.01%	0.04%	0.12%	0.07%	0.00%	0.02%	0.20%	0.18%	0.32%	0.06%	0.25%	0.12%	**0.64%**
MI	0.03%	0.02%	0.07%	0.16%	0.08%	0.01%	0.03%	0.19%	0.12%	**0.52%**	0.05%	0.36%	0.23%	**1.20%**
OH	0.03%	0.03%	0.05%	0.19%	0.12%	0.01%	0.05%	0.32%	0.23%	**0.42%**	0.05%	**0.47%**	0.34%	**1.31%**
WI	0.04%	0.00%	0.03%	0.11%	0.12%	0.01%	0.09%	0.12%	0.09%	0.23%	0.04%	0.24%	0.18%	**0.61%**
RUS	1.27%	1.82%	1.57%	5.45%	2.70%	0.51%	0.86%	5.67%	1.81%	4.88%	1.16%	11.20%	8.22%	37.67%

Note: Top 10 values (only among the five Midwest states) are identified in bold in the last two parts of table.

For Illinois in table 4-12, the absolute backward linkage affects in the entire U.S. economy record almost $19 billion if sector 1 is removed only from Illinois. The relative effect is 4.11% of the U.S. total output change when compared to the absolute total backward linkage effects with the hypothesis of extracting the sector 1 from the entire U.S. In other words, the absolute backward linkages effect is $465 billion when we assume sector 1 was removed from the entire U.S. economy system. Then, this figure is compared to the value representing the total backward linkage effect calculated when the sector 01 is isolated only from Illinois. The relative effect of sector 01 in Illinois to the entire U.S. economy system can be obtained. This value is much larger than 0.05% found in the last part of the table 4-12, which indicates that the output of sector 1 in Illinois accounts for 0.05% of the total U.S. output in 2007. Based on the backward linkages, the sector 9 (Metal) of Ohio has the strongest linkage to the entire U.S, while the sector 2 (Mining) of Wisconsin has the weakest linkage. Table 4-13 presents the total forward linkage effects for each extraction hypothesis in a same way as Table 4-12. The overall total forward linkages shows also very similar pattern as total backward linkages.

Table 4-13. Total forward linkages for each extraction hypothesis

	Extracted sector													
	01	02	03	04	05	06	07	08	09	10	11	12	13	14
From	Absolute effects (in 2007 U.S. million dollars)													
US	464755	763511	591800	1067732	755521	112909	376818	1778492	853691	1144205	334609	2458923	2368027	4597908
IL	17584	23164	26039	44605	59084	2284	26225	94449	88643	57602	12780	138179	175942	304163
IN	12692	6717	13688	23115	22797	1391	12225	63334	97962	75583	15239	61892	43448	102308
MI	10275	8325	22763	29749	23114	1389	16536	54136	66509	125821	11266	78206	77279	179837
OH	11755	12487	19395	37597	35970	2985	25303	94735	125400	102809	12601	107295	117229	199881
WI	16995	1752	9369	20339	38315	1801	41632	36577	51844	47962	11805	54559	60741	96042
RUS	413740	719525	502108	914430	625433	106920	310832	1489531	691194	865567	279011	2077871	2094932	4094414
	Relative effects (%, relative to the size of total forward linkages with the removal of the corresponding sector from the entire U.S.)													
IL	3.78%	3.03%	4.40%	4.18%	**7.82%**	2.02%	**6.96%**	5.31%	**10.38%**	5.03%	3.82%	5.62%	**7.43%**	6.62%
IN	2.73%	0.88%	2.31%	2.16%	3.02%	1.23%	3.24%	3.56%	**11.48%**	6.61%	4.55%	2.52%	1.83%	2.23%
MI	2.21%	1.09%	3.85%	2.79%	3.06%	1.23%	4.39%	3.04%	**7.79%**	**11.00%**	3.37%	3.18%	3.26%	3.91%
OH	2.53%	1.64%	3.28%	3.52%	4.76%	2.64%	6.71%	5.33%	**14.69%**	**8.99%**	3.77%	4.36%	4.95%	4.35%
WI	3.66%	0.23%	1.58%	1.90%	5.07%	1.60%	**11.05%**	2.06%	6.07%	4.19%	3.53%	2.22%	2.57%	2.09%
RUS	89.02%	94.24%	84.84%	85.64%	82.78%	94.70%	82.49%	83.75%	80.97%	75.65%	83.38%	84.50%	88.47%	89.05%
	Percentage of the output composition													
IL	0.05%	0.04%	0.07%	0.25%	0.20%	0.01%	0.05%	0.33%	0.16%	0.29%	0.05%	**0.64%**	**0.54%**	**1.86%**
IN	0.03%	0.01%	0.04%	0.12%	0.07%	0.00%	0.02%	0.20%	0.18%	0.32%	0.06%	0.25%	0.12%	**0.64%**
MI	0.03%	0.02%	0.07%	0.16%	0.08%	0.01%	0.03%	0.19%	0.12%	**0.52%**	0.05%	0.36%	0.23%	**1.20%**
OH	0.03%	0.03%	0.05%	0.19%	0.12%	0.01%	0.05%	0.32%	0.23%	**0.42%**	0.05%	**0.47%**	0.34%	**1.31%**
WI	0.04%	0.00%	0.03%	0.11%	0.12%	0.01%	0.09%	0.12%	0.09%	0.23%	0.04%	0.24%	0.18%	**0.61%**
RUS	1.27%	1.82%	1.57%	5.45%	2.70%	0.51%	0.86%	5.67%	1.81%	4.88%	1.16%	11.20%	8.22%	37.67%

Note: Top 10 values (only among the five Midwest states) are identified in bold in the last two parts of table.

Identifying the interregional and intersectoal economic linkages provides useful information to help policy-makers understand how their individual states interact with the rest of the US economy. Being able to trace the source of inputs and the destination of outputs, a better appreciation of an individual state's dependence on the performance of other states can be ascertained.

Chapter 5

Concluding Remarks

As a regional economy becomes more integrated in an open economy, prosperity or disruptions in one state now are now more likely to "spillover" to other states or regions. In other words, one region's or one state's future is more closely bound up with that of others. This type of structural change in a regional economy has been termed as a "hollowing-out" process; the accompanying changing spatial organization of production that is represented by "fragmentation of production" process together contribute significant explanatory factors to account for the enhanced spatial economic interdependence among regions. Through the hollowing-out process, each region depends more on other regions as their sources of production inputs or as the markets for their outputs. Therefore, each region seeks input sources and markets over wider geographical ranges and these processes lead to more economic interactions and trade among diverse regions or states. The fragmentation of production process allows each firm to operate their establishments in separate locales for a certain specific production process by taking the advantage of the economies of scale in one location and economies of scope across several locations and regions. This fragmentation of the production process promotes a locally specified production sequence within regions and greater integration across regions (see Romero *et al*, 2009). The reduction of transportation costs promoted in large part by deregulation and the advance in communications-related technology have accelerated these transformations. Such a changing spatial organization of production leads to increased interregional or interstate trade, and more complex and complicated nature of trade among regions in the entire regional economy system.

This dissertation explored the spatial structure and pattern of interregional trade based on the spatial interdependence explained by all the shifts in the production process and structure mentioned above. In addition, this dissertation sought to assess the role of interregional or interstate trade in determining the regional economic development.

The dissertation is composed of three main studies. First, this dissertation investigated the geographical pattern of U.S. interstate commodity flows for four different time periods, 1993, 1997, 2002, and 2007. This study employed two main analysis methods: trade Gini indices and flow matrix factor analysis. All these analyses were based on the U.S. CFS data. Although, generally speaking, the stability of spatial pattern of U.S. interstate commodity flows over time was observed, the analyses showed that the overall U.S. interstate commodity trade system has become less spatially focused in terms of the trade fields of each state. In particular, this study defined several major trading zones through flow matrix factor analysis, and these trading zones (or regions) of each U.S. state were shown to have expanded during the time periods of study. However, the analysis showed that the geographical contiguity still exist in the U.S. interstate commodity trade system. When the commodity-specific analyses were undertaken, some variations in the spatial pattern of commodity movements were detected: the movement of mining products is more spatially focused since they are bound up with their sources, whereas, on the other hand, manufactured goods show more spatially dispersed and extensive trade patterns. In a word, even subtle shifts in U.S. interstate commodity flows during the periods of study, which are expansion and redefinition of trading partnership, are observed; they are not radical or dramatic but they are subtle and important. Further, they may be indicative of shifts in spatial production structure explained by hollowing-out or production fragmentation. This study initially focused on depicting the geographical patterns of interstate trade, not mainly on the underlined forces to account for such movements. Future work, with access to more time series data, and greater spatial disaggregation, would be able to provide confirmation of some of the initial findings presented here.

Secondly, the dissertation assessed the significance of interregional trade in determining regional economic growth. A structural decomposition method was employed based on the U.S. six-region Multi-Region Interregional Input-Output Tables constructed by REAL at UIUC. The interregional input-output coefficient was decomposed using two different set sof coefficients: pure technical coefficient for each region and the interregional trade coefficient. The final demand change effect proved to be the most significant in generating the regional output growth between 1992 and 2007 in the U.S. regional economy, whereas the technical coefficient change effects showed mixed effects. For the interregional trade coefficient, the change resulting here were effects important. However, the analysis indicated that the interregional trade effects played as a positive agent in generating the regional output growth in the RUS while a negative effect was detected in the five Midwest states at more detailed level. When checking the change in the interstate trade coefficients itself in the Midwest during the period of analysis, the decrease in the interregional trade coefficient generated negative signs. At the same time, we can conclude that the hollowing-out process resulted in five Midwest states moving to wider search for the sources of their production inputs and the markets for their production outputs, so that the interstate trade coefficient with other Midwestern states decreased while that with the RUS increased. One of limitations this study was the limited data set that is only available at an aggregate spatial scale. In fact, changing spatial production structure might be detected at a smaller spatial scale such as metropolitan scale since the interaction changes due to structure change, for instance hollowing-out, has been shown to work hierarchically. Hence, some modifications with more detailed and disaggregate data set available will be one primary future research assignment. In addition, a measurement to assess the role of international trade for each region needs to be developed since the interaction of one region within a nation is not limited to the country but has increasingly involved interactions with the world economy.

In the final study, the dissertation examined the regional economic interdependence in the U.S. regional economy in 2007. The hypothetical extraction methods were employed and the analyses were based on the U.S. six-region Multi-Region Interregional Input-Output Account data for 2007. Based on the regional hypothetical extraction, there is a salient hierarchical structure of spatial linkages among six regions in the U.S. in 2007. In absolute terms, the larger economies have strong backward and forward linkages with other regions in the entire regional economy system. In the relative terms, the linkages of the small and open economies turned out to be the most significant. At the bilateral level, clear hierarchies of dependencies among regions were identified. As for the sectoral linkages, the combined hypothetical extraction methods were applied. Some variations were detected by sector as well as by region. In other words, the impact of a specific sector in each individual regional varies. This study emphasized that an appropriate policy should be required for each region after considering the interregional and intersectoral interdependence in the context of the entire regional economy. Identifying the interregional and intersectoral economic linkages among regions is very useful in developing guidelines for regional economic developers or policy makers to prioritize which sector they specialize in to maximize the regional economic growth.

This dissertation provided one perspective in understanding the U.S. interregional trade and spatial economic interdependence within the entire U.S. regional economy, and implied the increasing role of interregional trade. More regional “spillover” effects through the interregional interaction would be anticipated and the increasing interregional or interstate trade is expected to enhance regions' complementarity as well as competitiveness. One might suspect that transportation infrastructure investment would become more important in developing and promoting the entire regional economic system. From this point of view, the assessment of the regional economic impact of transportation infrastructure development would be one of the more important future research assignments. An integrated model with an interregional input-output model and a transportation network model facilitate the analysis of such investments. As the same time, with further integration with environmental modules, it would be possible to assess the potential negative externalities generated by increased trade – for example, increased pollution, increased consumption of non-rewable energy inputs and so forth. Further, an evaluation of the interregional social welfare impacts could be accomplished to explore the degree to which the benefits and costs generate a more or less equitable allocation of welfare outcomes.

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