Impact of Modern Logistics on Industrial Location Choice and Property Markets

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ABSTRACT

The debate on the impact of modern logistics on industrial location choice and property markets focuses on (1) whether modern inventory control and supply-chain configuration consolidate manufacturing and distribution locations and (2) whether modern logistics have reduced the demand for industrial real estate. In this research, I test the hypothesis that modern logistics have been restructuring industrial manufacturing and distribution networks, dispersing firms into certain regions to achieve the economies of dispersion, and reducing the demand for industrial space per unit of industrial output. The methodology used includes (a) theoretical analysis, (b) statistical and econometric analysis, (c) case studies, and (d) comparative analysis. Because the theoretical analysis does not provide a clear conclusion, I rely on empirical analyses to derive the actual impact or implications.

Principle findings from the U.S. empirical study include (1) the changes in the distribution sector have a more significant impact on industrial location choice and property markets than the changes in the manufacturing sector; (2) both manufacturing and distribution industries have been dispersed in the past two decades; (3) improvement of inventory control is almost ubiquitous and, within a supply chain, certain players' gains are not necessarily at the cost of their suppliers' or customers' losses; (4) the traditional partial stock-adjustment model using yearly data does not explain the industrial property market well.

Major findings from the China case studies include (1) modern logistics enable manufacturers to achieve cost reductions and service-level improvements simultaneously, and the impacts on their industrial location choice and space demand are consistent with the empirical findings of their U.S. counterparts; (2) with the expansion of globalization, advances in information technology, development of efficient markets, and increased demand from sophisticated customers, location choice and demand for industrial space will continue to be determined by the requirements of efficient supply chains.

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ABBREVIATIONS

AIC = Akaike Information Criterion
B2B = Business to Business
B2C = Business to Customer
BOF = Basic Oxygen Furnace
CDC = Centralized Distribution Center
CRM = Customer Relationship Management
DRP = Distribution Resource Planning
EAF = Electric Arc Furnace
EDI = Electronic Data Interchange
EOQ = Economic Ordering Quantity
ERP = Enterprise Resource Planning
GDP = Gross Domestic Product
GICS = Global Industry Classification Standard
GPS = Global Positioning System
IRE = Industrial Real Estate
IT = Information Technology
JIT = Just-in-Time
MIS = Management Information System
MRP = Material Requirement Planning
MSA = Metropolitan Statistical Area
NAICS = North American Industrial Classification System
NECMA = New England County Metropolitan Area
QR = Quick Response
R&D = Research and Development
RFID = Radio-Frequency-Identification
SCM = Supply Chain Management
SEC = Securities and Exchange Commission
SKU = Store-Keeping-Unit
VAR = Vector-autoregressive
VIF = Variance-Inflation Factor

CHAPTER 1
INTRODUCTION

How and why economic activities choose to locate among different regions is an important factor to determine how fast a region grows or declines. Economists and researchers (Hirschman 1958, Norton and Rees 1979, Porter 1990, Krugman 1995) have developed many theories, such as comparative and competitive advantage, to explain underlying factors. In addition, increasing returns-to-scale, spillover effects, and increasingly interrelated labor markets all contribute to the economies of agglomeration and regional economic growth. Regional growth essentially determines the demand for industrial space, which, in turn, has a fundamental impact on the industrial property market.

Since the 1990s, supply-chain management (SCM) has emerged as a core component in many firms' business models. Although many researchers find that the implementation of modern inventory controls and supply-chain strategies has been influencing industrial location choice and property markets, the actual impact is still in debate. Typically, the debate focuses on two issues: (1) the location choice and (2) the demand for industrial space. For the first issue, the debate focuses on whether modern logistics, primarily the modern inventory control and supply-chain configuration, consolidate or disperse manufacturing and distribution locations across regions. For the second issue, the debate focuses on whether modern logistics have significantly reduced the demand for industrial real estate given the two competing forces of (a) the increased customer-service levels that require firms to hold inventories and (b) firms' cost-minimizing objectives that lead them to reduce inventories.

In this research, I test the hypothesis that *modern logistics have been restructuring industrial manufacturing and distribution networks, dispersing firms into certain regions to achieve economies of dispersion, and reducing the demand for industrial space per unit of industrial output*. With location choice and demand for industrial space issues playing an increasingly important role in China's regional development, I conduct case studies to compare the applications of SCM in China and in the United States.

The structure of this study is as follows. In Chapter 2, I review pertinent literature on the relationship among SCM, industrial location choice, and industrial property markets, given that the first is hypothesized as the major factor underlying the changes in the latter two and the latter two interact with each other. Then, in Chapter 3, I study fundamental logistic models, their applications in different industries, and implications on industrial location choice and demand for industrial space. In Chapter 4, I perform an empirical analysis on industrial location choice in 30 major U.S. industrial regions/markets, and investigate the changing patterns of inventory holdings in 65 U.S. manufacturing, distribution, and retailing sectors by studying 417 major firms' annual financial statements. I continue the empirical analysis in Chapter 5, studying the impact of industrial mix and changed inventory holdings on the industrial property market. In Chapter 6, I conduct case studies of selected manufacturing firms in China, comparing them with the cases in the United States and deriving the implications of their modern logistic applications. I finally draw conclusions in Chapter 7. The methodology of this research consists of four steps: (1) theoretical analysis, (2) empirical statistical analysis, (3) case studies, and (4) comparative analysis.

My research contributions include (a) bridging the literature gap between logistics in management science and industrial-location choice/property markets in regional and urban economics, (b) performing metropolitan-area-and-industrial-sector-based analyses of industrial location choice and industrial space markets, deriving the implications concerning modern logistics' actual impact in different industrial sectors, and (c) comparing case studies in China and the United States, deriving policy implications for logistic-based industrial development in China.

CHAPTER 2
LITERATURE REVIEW

As modern logistics and supply-chain management (SCM) have become the core component of many manufacturing firms' business models, researchers are debating their impacts on industrial location choice and property markets. They argue that the impacts are primarily attributed to restructured supply-chain networks and changed demand for industrial inventories. In this Chapter, I review literature on the two major issues: (1) impact of SCM on industrial restructuring, and (2) how SCM affects industrial location choice and property markets.

2.1. Supply Chain Management and Industrial Restructuring

In the logistics and management-science literature, a supply chain is often defined, broadly, as an integrated process wherein manufacturers acquire raw materials from suppliers, convert these raw materials into final products, and deliver the products to end customers (Beamon, 1998). The initial objective of SCM is to reduce firms' inventory and transportation costs and/or to improve their service levels. When researchers study supply chains in an industrial or regional context, they are concerned about the roles of SCM in industrial restructuring.

Flaherty (1996) summarizes the approaches of SCM into two categories: (1) changing physical structure of the manufacturing and logistic network, including locations and capacities of plants, warehouses, and distribution centers; and (2) changing coordination mechanisms – including order processing, demand forecasting, and purchasing decision-making. In terms of structural approaches in SCM, cost reduction by moving to lower labor-cost regions often outstrips increased delivery costs if transportation costs and duties are low. In addition, improvement of the coordination mechanism makes it possible for an industry or a firm to access more sophisticated products and services at a greater distance with higher quality than before.

Ellram (1990) cites the Japanese automobile industry as a good example of successful SCM. In the supply chain, automobile manufacturers acquire parts from a number of trading companies, who share trade information with their subcontractors. These subcontractors also share information with transportation firms who provide timely delivery of raw materials and intermediate goods. In the supply chain, dealers sell cars and send the demand information to distributors and manufacturers to coordinate production and distribution. Such a mechanism enables these automobile firms to have more economies of scale and fewer internal duplication efforts than their competitors.

Glasmeier and Kibler (1996) explain the role that SCM has played in the wholesaling industry. With the dramatic improvement in logistic systems, particularly the advance of electronic data interchange (EDI) and the deregulation of transportation, they find that economic power has shifted to end customers. Such a trend has greatly restructured the wholesaling industry in demand forecasting and final-product delivery.

Traditionally, manufacturers forecasted their demand based on the historical data, and then acquired raw materials from suppliers, manufactured final products, and shipped these final products to retailers. Such a "push" system often caused a high-level of inventory because of volatile demand and incorrect forecasts. Recently, with the help of computer-based information interchange, suppliers, manufacturers, distributors, and retailers can share their information in a much faster and more precise mode. Manufacturers can determine their production directly based on sales information from the end market. According to Simichi-Levi, et al. (2000), such a “pull” system has replaced the old “push” system in some industries and enabled all the business entities in the supply chain to maintain low inventory levels. Wal-Mart’s remarkable success since the 1980s is an excellent example of the application of such “pull” systems based on sophisticated computer information systems and cross-docking techniques.

By analyzing logistic systems of Dell and Proctor and Gamble (P&G), Copacino and Byrnes (2001) conclude that successful supply-chain strategies should provide certain advantages that cannot be provided by competitors so as to reduce the competitors’ access to given market segments. Dell’s direct-to-customer channel and P&G’s SCM strategy of direct-distribution to major accounts enable both companies to maintain excellent relationships with their customers. In return, companies receive real-time feedback from customers, thereby reducing dealer inventories and improving service levels.

From the theoretical perspective, operation researchers and management scientists have conducted extensive studies on the factors that underlie the economies of modern logistic systems and proposed many theoretical models (MacCormack 1994, Flaherty 1996, Simchi-Levi, et al. 2000, Masters 2002). For instance, in demand forecasting, an important component of inventory control, demand variability often increases along the supply chain when the forecasting is conducted at each stage in a multi-echelon system. In operations research, such an increase in variability is often referred to as the “bullwhip effect”—if the variance of the customer demand seen by the retailer is Var(D), then the variance of the ordering quantity placed by that retailer to the manufacturer, Var(Q), relative to the variance of customer demand follows:

$$\frac{Var(Q)}{Var(D)} \geq 1 + \frac{2L}{p} + \frac{2L^2}{p^2}$$

where L denotes the lead-time and p is the number of inventory observations during the given time (Simchi-Levi and Watson, 2001). To cope with the “bullwhip effect”, one approach is to reduce uncertainty by centralizing demand information, as discussed in the above examples of the automobile and wholesale industries. Another approach is to reduce lead-time. Strategies that use advanced information technology to obtain timely and precise data, such as electronic data exchange (EDI) and enterprise resource planning (ERP), have proven useful (Simchi-Levi et al. 2000). If we consider information sharing as a strategy of changing coordination mechanisms, the actual impacts of SCM on industrial restructuring are consistent with the two categories of impacts proposed by Flaherty (1996).

2.2. Modern Logistics and Industrial Location Choice

Traditionally, economists and regional scholars suggest that a firm’s location choice is based on (1) labor costs and quality, (2) market and transportation access, and (3) enthusiasm of pro-business communities

(Dipasquale and Wheaton 1996). In addition, the economies of scale and the economies of agglomeration are also factors underlying many firms' location choice. As globalization is expanding and transportation costs decreasing as a share of the total cost, modern firms have more flexibility in their SCM than before. Because SCM has been a core component in many firms' business models, their supply chains and logistic systems are expected directly or indirectly to determine their industrial location choice and demand for industrial space at each location.

McCann (1998) proposes a logistic-cost-based approach to study the economics of industrial location and conducts an empirical study on the Scottish electronic industry. Using a model based on the economic-ordering-quantity (EOQ) concept, he finds that the role played by input factor prices and product market prices in location behavior becomes dependent on the relationship between the frequency of shipment and the distance of shipment. Although his approach acts as a bridge to connect logistics and location-choice models, a critical problem lies in his assumption that a firm makes its location decision primarily based on the total direct cost. As many researchers (Castells 1996, DiPasquale and Wheaton 1996, Porter 2001, Polenske 2003) point out, lowering cost may not be the prime reason why a firm selects a location. Instead, it may do so to enhance its market access and market control.

In addition to such traditional criteria as inventory costs, transportation costs, market access, and service levels, Chen (2002) finds that environmental costs can be another significant factor that determines where firms locate. In her study of the cokemaking industry in China's Shanxi Province, she finds that, if the costs of pollution and energy consumption outstrip the cost savings from direct transportation and consolidation of plants, cokemaking firms prefer dispersed production-distribution networks with low-capacity plants. Therefore, the key consideration in the supply-chain design and the firm's location choice may be associated with the government's regulations that place strict constraints on pollution emissions and energy sustainability.

Pereira (1996) investigates the impacts of supply chains on firms' location choice in the Chicago metalworking sector. He specifies twelve characteristics, including price, speed, safety, accessibility, reliability, tracing, etc., as measures of service levels and separates mode characteristics by inbound and outbound. On the inbound side, firms list their top five priorities as price, speed, reliability, accessibility, and tracing. On the outbound side, they list their top five characteristics as speed, reliability, price, safety, and accessibility. His findings show that nine characteristics of the twelve, excluding connectivity, coordination, and intermediacy, help determine the role of transportation in production and distribution processes. Thus, in contrast to neoclassical location theories in which transport price is the chief determination of location decision, Pereira finds a more complex set of factors related to the entire supply-chain and that the factors vary for in-bound and out-bound shipments.

Polenske (2003) develops the concept of *dispersion economies* with the belief that various factors are now causing some firms to move away (disperse) from concentrated centers of economic activity, and a considerable amount of this dispersal occurs along supply chains. She defines dispersion economies as *the benefits that accrue to firms from spatially dispersing their location in order to achieve cost savings and service-level improvements*. She argues that, as power shifts to end customers, successful supply chains offer certain advantages that cannot be provided by competitors so as to reduce the competitors' access to specific market segments.

In summary, from traditional neoclassic location theories to the concept of the dispersion economies, researchers find that SCM has been playing an increasingly important role in firms' location decisions in the manufacturing and distribution sectors. In particular, Polenske's definition of the dispersion economies highlights the underlying reasons for the dispersion economies. All this literatures, however, is based on simple theoretical analyses or individual case studies; a systematic theoretical and empirical analysis is needed to test the actual impact of SCM on industrial location choice.

2.3. Modern Logistics and Industrial Space Market

In order to measure the location choice in different industries, the demand for industrial space can be a good indicator. As Geltner and Miller (2001) discuss in their book, commercial real-estate investments are essentially determined by the interactions between the two markets: the space market for the usage of real properties and the asset market for the ownership of real-estate assets. In the space market, it is the regional economic growth and industrial location choice that eventually determine the demand for commercial real estate.

The supply of and the demand for real-estate physical assets are both location and type specific, which results in a segmented real-estate space market. The typical geographic unit of space market segmentation is a metropolitan area; while in each area, the real-estate market is segmented by property-usage type. The four major types of commercial real estate are office, retail, industrial, and multifamily residential.

The industrial space market includes two major sub-markets, manufacturing and distribution. Mueller and Laposa (1994) suggest that the demand for distribution space in a market/region is basically determined by whether it is located on global logistic routes. Wheaton (2004) further argues that logistic requirements have been much more important than real estate rents for firms to select manufacturing and distribution sites. He finds that the demand for industrial properties by the manufacturing sector has been stable for the last decade, while the demand for industrial properties by the distribution sector, which was closely related to logistic and inventory management, has been growing steadily.

Because of the implementation of such modern logistic systems as just-in-time in the automobile industry, cross-docking in the retail/wholesale industry, quick-response in the apparel industry, and direct-shipping in the computer-manufacturing industry, the velocity of goods flows has increased substantially (AMB 2004). Property & Portfolio Research (PPR), a Boston-based economics and finance research firm, finds (2000) that great efficiencies in SCM have caused the correlation between the real GDP and the occupied warehouse space to decline since the mid 1990s. Such technologies as the EDI used since the 1980s and internet-based information systems since the 1990s have substantially reduced the lead-time of ordering and delivering, thereby lowering the required inventory given the same sales volume. Recently, a new technology, the Radio-Frequency-Identification (RFID), has been adopted by some large firms and is expected to further reduce the total demand for warehouse stocks. Similar to many previous logistic technological advances, RFID provides faster and more accurate information flows. Although the technology is not widely used as of 2005, the list of companies that have been implementing or planning to implement the RFID includes Wal-Mart, Gillette, Procter & Gamble, Home Depot, and Kraft.

However, because of globalization, outsourcing, store-keeping-unit (SKU) proliferation, i.e., increased variations of the same products, and shortened product life cycles, modern logistics have become increasingly complex. In particular, globalization of supply chains, such as offshore manufacturing, has significantly increased the lead-time of distribution and difficulties in demand forecasting. As a result, inventories may rise considerably in some industries or for certain products. Researchers have been debating whether modern logistics have truly significantly reduced the total inventory and, in turn, the total demand for industrial space given the increased industrial output. Research by AMB Property Corporation (2005), a firm based in San Francisco, on U.S. inventories suggests that, although technological advances have improved the inventory management, they have not lowered the total inventory requirement. Inventories relative to sales had been decreasing from about four months' worth of sales in 1950 to about two months' worth of sales in 2003, but on an absolute basis, the total U.S. inventory continued to grow as the economy grew. Between 1996 and 2004, the total inventory grew by almost 20 percent.

Based on their analysis, AMB researchers argue that, no matter how fast the supply chain operates, there will always be mismatches and disruptions, and safety stock will be needed to deal with stochastic demand and to achieve required service levels. Also, the rising customer demand for lower stock-out rates and more customized products may push inventory levels even higher than before. Contrary to PPR and Wheaton's findings, AMB researchers find that the deviations in the correlation of inventory to GDP and to warehouse stocks over the past two decades have been small and the ratios fluctuate around the mean. They conclude that changes in supply chains affect different locations differently and the impact of modern logistics on the demand for industrial space might be insignificant.

2.4. Summary

Modern logistics, including various inventory-control techniques and SCM strategies, have had an extensive impact on industrial restructuring, but their actual impact on industrial location choice and property markets is still in debate. Few if any researchers have performed a systematic analysis of the actual impact. In this research, I conduct theoretical and empirical analyses on the trend and the magnitude of the actual impact in the United States. In addition, although China has become an important manufacturing base in the world, the study of Chinese firms' SCM is still limited; it would be interesting and useful to study their SCM practices and related impacts on industrial location choice and property markets. Comparing the findings from China with those from the U.S. empirical studies may provide valuable implications on the logistics-based industrial and regional development in the country.

To conduct the research, I use the following four steps: (1) summarize key variables in fundamental logistic models and compare the applications of major logistic-systems in different industrial sectors, (2) conduct macro-level empirical analysis on industrial consolidation/dispersion and the changing patterns of manufacturing/distribution firms' inventory holdings, (3) build econometric models to investigate the actual impacts of industrial mix and inventory holdings on the demand for industrial space, and (4) conduct case studies and comparative analysis of representative Chinese manufacturing firms, deriving the implications of modern logistics' actual and potential impacts on industrial location choice and property markets in China.

CHAPTER 3
THEORETICAL ANALYSIS

As discussed in Chapter 2, over the past several decades, management attention has increasingly focused on the firm's inventory control to reduce costs and improve the level of customer service. Inventory control through the implementation of efficient modern logistic systems and successful SCM strategies has been an important tool to improve a firm's rate of return on assets.

In this Chapter, I start the theoretical analysis by discussing basic logistic models. Then, by incorporating location factors and level-of-service considerations into the models, I generate a function of the inventory demand of key variables. I analyze the relationships among the key variables and derive the impact implications of modern logistic techniques/strategies on the inventory demand and the industrial location choice. The results are expected to provide a theoretical ground to support or reject the proposed hypothesis. As shown in the following analysis, however, the theoretical analysis provides some implications on the hypothesized impacts, but I cannot reach a clear conclusion. I therefore conduct empirical analysis in the next two chapters.

3.1 Logistic Models

By definition, inventory is material that the firm obtains in advance of need, holds until it is needed, and then uses, consumes, incorporates into a product, sells, or otherwise disposes. There are two major reasons to hold inventory: (1) to buffer uncertainty in demand, supply, and delivery, and (2) to provide scale economies in procurement, production, and transportation. There are four types of costs related to inventory: (a) purchasing cost, (b) ordering cost, (c) holding cost, including obsolesce cost, and (d) shortage cost (Masters, 2002).

General inventory modeling includes three dimensions. First, regarding the type of inventory stocks, there are deterministic cycle stocks and stochastic safety stocks. Second, based on the planning horizon, researchers and practitioners classify models into three categories: indefinite planning horizon, finite planning horizon, and single period. Third, for complexity, models are distinguished by single- versus multiple-items, locations, and echelons. (Masters, 2002)

Deterministic Cycle Stock

The classic Wilson's economic-order quantity (EOQ) model determines optimal cycle stocks. If we assume demand is uniform, continuous, and known with certainty, lead-time is zero, demand rate is high, item value is low (such as basic consumer goods), and no shortage is allowed, we can model the total inventory cost as:

$$TC[Q] = \frac{C_o D}{Q} + \frac{C_h C_p Q}{2} \tag{3.1}$$

where C_o represents ordering cost (dollars per order), C_h represents holding cost (dollars per dollar held per year), C_p represents purchasing cost (dollars per unit), Q represents ordering quantity (units per order), D represents average annual demand (units per year). Setting the first-order derivative equal to zero, we obtain Wilson's EOQ, Q_w:

$$Q^* = Q_w = \sqrt{\frac{2DC_o}{C_h C_p}} . \tag{3.2}$$

Assume the usage of the inventory follows a linear pattern, then the average inventory equals *Q/2*, and it follows that, for cycle stock, the turnover rate *T=D/(Q/2)=2D/Q* and the optimal turnover rate is $T^* = \frac{2D}{Q^*} = \sqrt{\frac{2DC_h C_p}{C_o}}$. On an aggregate system-wide basis, with N items, each with D_i, Q_i *, C_{pi}, the system-wide turnover rate is:

$$T^*_{SYSTEM} = \frac{2\sum_{i=1}^{N} D_i C_{pi}}{\sum_{i=1}^{N} Q_i{}^* C_{pi}} \tag{3.3}$$

In practice, demand is estimated and modeled separately for each item at each storage location l, and prices are assigned to each item i. Ordering costs and holding costs are often computed as system-wide parameters, usually on an average-cost basis. Thus, the optimal lot size is set to be $Q_{w[i,l]}{}^* = \sqrt{\frac{2D_{[i,l]}C_o}{C_h C_{p[i]}}}$, and the optimal order cycle time for each item is:

$$\frac{Q_{w[i,l]}}{D} = \sqrt{\frac{2C_o}{D_{[i,l]} C_h C_{p[i]}}} . \tag{3.4}$$

Equation (3.4) implies that items with high values or high usage should be ordered more frequently than items with low values or low usage. Regarding the optimal cycle-stock level, i.e., *Q*/2* if we assume a linear usage pattern, products with high usage, high ordering cost, low holding cost and low unit price should be ordered in high quantity and, if we assume no substitution effect and hold the unit physical inventory space constant, such products should require large inventory space.

From a simple EOQ perspective, if an item can be stocked at a number of different locations to satisfy global demand and if we assume a uniform unit inventory cost, the total demand rate *D* can be satisfied from either one inventory location or partitioned into *n* equal demand rates, d_i, each with its own inventory location. Then, assume C_o, C_h, C_p are the same at all locations, we have:

$$D=\sum_{i=1}^{n} d_i \ ; \ d_i = \frac{D}{n}; Q^* = \sqrt{\frac{2DC_o}{C_h C_p}} \ ; \ q_i^* = \sqrt{\frac{2d_i C_o}{C_h C_p}} \ .$$

The total optimal order quantity over multiple locations is:

$$\sum_{i=1}^{n} q_i^* = \sqrt{n} Q^* \qquad (3.5)$$

and the total cost is: $\sum_{i=1}^{n} TC[q_i^*] = \sqrt{n} TC[Q^*]$, which we refer to as the square-root-law. Because n>1 and $TC[Q^*]>0$, $\sqrt{n}TC[Q^*] > TC[Q^*]$. Thus, by considering the cycle stock, this "square-root-law" suggests that decentralizing inventories would incur more inventory costs than centralizing ones. Summarizing the above models, we can write the function of the optimal cycle stock, INV_{CYCLE}^*, as:

$$INV_{CYCLE}^* = \sum_{i=1}^{n} q_i^* = F(n, Q^*) = F(n, \sqrt{\frac{2DC_o}{C_h C_p}}) \ . \qquad (3.6)$$

Statistical Safety Stock

Demand forecasting always involves uncertainty. A stock-out can occur when demand during lead-time exceeds the reorder point R (the inventory level when reordering). When lead-time usage is forecasted with a time-series technique such as exponential smoothing, the forecast errors tend to be approximately normally distributed, even if the demand process is not normally distributed. Inventory studies suggest two basic types of stochastic model: continuous review and periodic review (Graves, 2003). The first one is usually applied to high-value products, while the second is applied to low-value products and coordinated parts.

In the continuous-review model, a general approach is to set the expected inventory level as: $E[Inv] = \frac{Q}{2} + z\sigma\sqrt{L}$, where Q represents the order quantity, z represents the z-value in the normal distribution table, σ represents the standard deviation of demand per unit of time, and L represents replenishment lead-time. Similarly, in the periodic-review model, the expected inventory is: $E[Inv] = \frac{r\mu}{2} + z\sigma\sqrt{r+L}$, where r represents reorder interval and μ represents the expected demand per unit of time. Therefore, products with more volatile demand and a longer lead-time would require more safety stocks and more inventory space that other types of products if the unit inventory space is held constant. (Graves, 2003)

Summarized into a general form, the expected inventory is: $E[Inv] = Inv_{CYCLE} + K\sigma$, and the reorder point is: $R = d' + K\sigma$, where d' is the expected lead-time usage and K is the safety-stock factor. When considering stochastic demand, we define the service level (SL) as the probability of not stocking out during lead-time: $SL = \Pr(d \le R) = \Pr(d \le d' + K\sigma)$, where d is the actual usage during lead-time and E[d]=d'. The probability of stock-out is

$P[SO]=1-SL$, and the expected units short (i.e., units not supplied in time) given the reorder point R are: $E[UnitsShort \mid R]=E[US \mid R]=\sum_{d=R}^{\infty}(d-R)p[d]$. If we assume d follows a continuous probability density function f(x), then $E[US \mid R]=\int_{R}^{\infty}(x-R)f(x)dx$. For the normal distribution, we can use the *Table of Unit Normal Loss Integrals* (Masters 2002) to convert safety-stock factor K into standard deviation's worth of expected units short: $E[US]=N[K]\sigma$, where N[K] is derived from the table.

Typically, back orders would incur backorder costs. Let C_B denote unit backorder costs (dollars lost per unit delayed), then the total average annual cost including the cycle stock and the safety stock in the backorder case would be:

$$TC[Q,R]=\frac{C_o D}{Q}+\frac{C_h C_p Q}{2}+C_h C_p ks+\frac{C_B N[K]\sigma D}{Q}. \quad (3.7)$$

Taking partial derivatives with respect to Q and R and setting each equal to zero yields two equations:

$$P[SO \mid R]^*=\frac{Q^* C_h C_p}{DC_B};\ Q^*=\sqrt{\frac{2D(C_o+C_B N[K^*]\sigma)}{C_h C_p}}. \quad (3.8)$$

From the first equation in (3.8) we can compute SL*=1-P[SO]*, then find K* in the normal distribution table and compute Q*. To compute P[SO]*, however, we need to know Q*, so that this would be an iterative process. We can set $Q^*=Q_w$ and iterate until the equations converge to a solution (Masters 2002). In a general form, we write the function of the optimal total inventory $E[INV]^*$ as:

$$E[INV]^*=INV_{CYCLE}^*+E[INV_{SAFETY}^*]=F(n,D,C_o,C_h,C_p,C_B,z,\sigma,L) \quad (3.9)$$

where n is the number of inventory sites, D is the average demand rate, C_o is ordering cost, C_h is holding cost, C_p is the unit purchasing price, C_B is backorder cost, z is based on the required service level, σ measures the volatility of demand rate, which is determined by actual demand volatility and the forecasting techniques used, and L is the replenishment lead time. For a typical EOQ-based logistic system, we have the following relationships among variables:

$$\frac{\partial E[INV]^*}{\partial n} > 0; \ \frac{\partial E[INV]^*}{\partial D} > 0; \ \frac{\partial E[INV]^*}{\partial C_o} > 0;$$

$$\frac{\partial E[INV]^*}{\partial C_h} < 0; \ \frac{\partial E[INV]^*}{\partial C_p} < 0; \ \frac{\partial E[INV]^*}{\partial C_B} > 0;$$

$$\frac{\partial E[INV]^*}{\partial z} > 0; \ \frac{\partial E[INV]^*}{\partial \sigma} > 0; \ \frac{\partial E[INV]^*}{\partial L} > 0. \quad (3.10)$$

The total cost in a logistic system includes both inventory and transportation costs. Let transportation cost T[L] be a function of L, the average replenishment time across all distribution sites. In general, T[L] is a monotonically decreasing function of the average replenishment time, i.e., $\partial T/\partial L<0$ and $\partial^2 T/\partial L>0$. We can incorporate transportation cost in the inventory decision by the function: $E[INV]^* = F(n, D, C_o, C_h, C_p, C_B, z, \sigma, L, \tau)$, where τ represents unit delivery cost, and we generally have:

$$\frac{\partial E[INV]^*}{\partial \tau} > 0. \quad (3.11)$$

Typically, there is a trade-off between transportation cost and inventory cost in the total cost as lead-time changes. Since the 1980s, the advance in transportation technologies and the deregulation in the U.S. transportation industry have enabled transportation firms to differentiate services and lower prices, and transportation cost has since become a less important factor for firms to consider in the supply-chain design (Polenske and Li, 2003). For instance, in 1987, transportation direct costs averaged less than three percent of total costs for all except one of 79 sectors in the United States and have since declined further (U.S. Department of Commerce, 1994). Lower transportation costs have enabled firms to have more flexibility than before in supply-chain design when choosing transportation modes and routes.

3.2 Applications of Modern Logistic Systems

In the remaining part of this chapter, I discuss the applications of modern logistic systems and their potential impact on industrial-location choice and property markets based on the discussed theoretical models.

Material Requirement Planning /Distribution Resource Planning

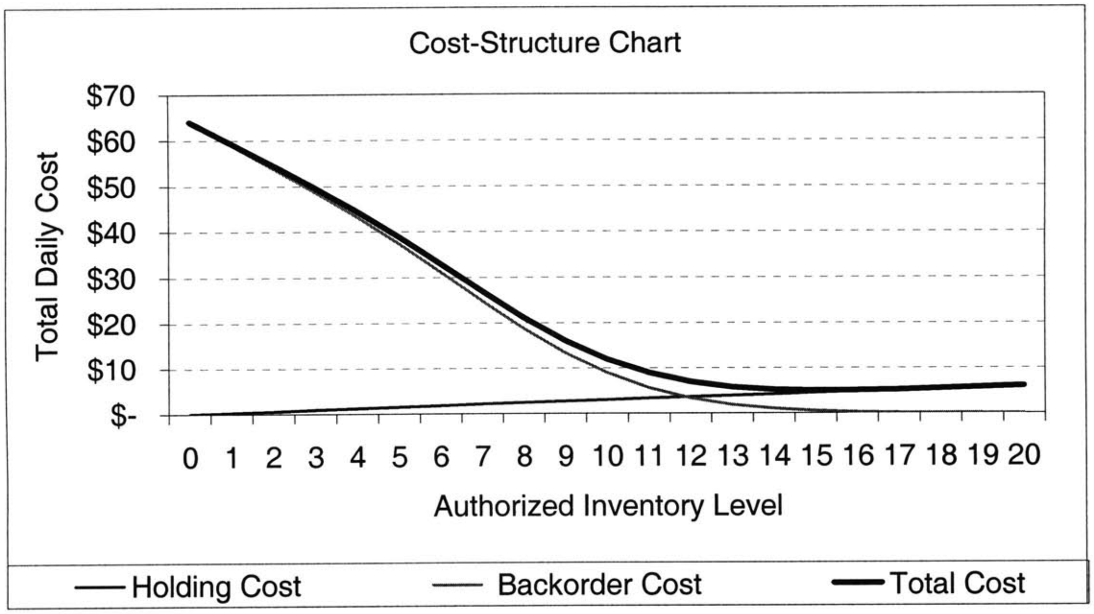
In the traditional EOQ-based and fixed-lot-size model, we assume (1) demand is continuous, (2) average usage per period is stable over time, and (3) usage in any given period is uncertain in advance. Inventory control in the production environment, however, is often different: there are many final products and intermediate components in the production process, the product contract structure is complex, and production may create lumpy demand for a certain period. Material requirements planning (MRP) is an inventory control system used in the production environment that is closely related to the "Just-in-Time" system originated by Japanese automobile industry in the 1980s and then widely adopted in many other manufacturing industries (Masters 2002). MRP is essentially a scheduling algorithm for the production process. It replaces the safety stock required for volatile demand by the safety time required for uncertainty in delivery lead-time. Successful implementation of MRP systems lowers the inventory level and stock-out rate at the same time.

Distribution resource planning (DRP) is the application of the MRP principles and techniques to distribution inventories. It is the scheduling algorithm applied to multi-echelon distribution systems. Analysts use it to replace inventory with information, using simple heuristic rules and focusing on quantities and times instead of costs in inventory control. Theoretically, by implementing MRP and DRP, firms can lower ordering costs, C_o, and demand volatility σ, thereby reducing the total inventory level (Masters 2002). MRP and DRP systems have been widely used in the industries with multiple semi- and final-products, continuous and stable demand, and multi-echelon production and distribution networks. Typical industries include automobile and machinery-manufacturing industries.

Quick-Response System

Most EOQ-based and MRP-DRP systems assume high volume demand and batch replenishment. According to the basic EOQ model, however, if the demand rate, D, and ordering cost, C_o, are low enough and if the unit price, C_p, and holding cost, C_h, are high enough, the average optimal ordering quantity, Q^*, might be one or even less than one in a given period of time. In industries such as apparel and retail/wholesale that have small demand rates for each individual store-keeping unit (SKU), or in the computer-manufacturing industry that observes high unit purchase and holding costs (including costs for rapid obsolescence), EOQ-based or MRP-DRP systems may have intrinsic problems in inventory control because the demand rate, D, is assumed to be greater than one in these systems. For the past two decades, quick-response (QR), a system with no fixed lot size imposed and stock replenished in reaction to real-time sales information, has been widely adopted in related industries (Hammond, 1990).

In a QR system, products are reordered on a one-for-one base, which is like a pipeline inventory system with stochastic demand and re-supply time. Researchers often model a QR system as an $M/G/\infty$ queuing system, where M indicates that the demand rate follows a Poisson or exponential distribution, G indicates the re-supply process may follow any probability distribution, and ∞ indicates that there are infinite servers and therefore no queues in the system (Masters 2002). The optimal inventory level in a QR system is a function of holding costs and backorder costs. For a typical QR system, the total backorder cost for an individual SKU declines rapidly as Q^* increases from zero, while the total holding cost increases at a much lower rate (Figure 3-1). As a result, the optimal authorized inventory level would be small for each SKU. Researchers had the concern that shipping costs might rise substantially due to frequent and small replenishment quantities, but empirical studies show that firms can ship many products at the same time with each in a low volume while the aggregate shipping volume remains large (Simchi-Levi 2002).



Source: calculated by the author (2004) based on the data given in Masters (2004)

Figure 3-1.
Cost Structure of a Typical Quick-Response System

In practice, QR systems have been implemented by firms in the industries with high holding costs (including obsolescence costs), multiple product types, and low demand rates for individual SKUs. Such industries include apparel, food products, pharmaceuticals, and retail/wholesales (Simchi-Levi 2002).

Make-to-Order/Electronic-Commerce

With the dramatic advance of information technology, particularly the implementation of intranet- and internet-based management information systems, firms in manufacturing/distribution/retail industries have reframed their business models and implemented modern logistic systems to explore the capacity of new technologies. The internet-based make-to-order model employed by computer-manufacturing companies, such as Dell, enables the end customer to place the order directly through the internet and, after receiving the order, the firm immediately starts assembling the product based on the customer's specific requirements and then delivers the finished product to the customer directly. The manufacturer can manage the demand of customers on a weekly or daily basis with timely data (Byrnes, 2003). Such operation models enable the manufacturing firm to bypass the intermediaries and reduce the inventory of finished goods.

Advanced information technologies also enable firms to obtain accurate and timely sales information, and thereby mitigate bullwhip effects in the supply chain and reduce safety stocks. Technologies, such as global positioning system (GPS)-based cross-docking and computer-based enterprise-resource-planning (ERP) and customer-relationship-management (CRM) systems, have enabled many firms to improve the visibility of transaction data in the supply chain and reduce the volatility in demand forecasting. As a result, by holding other things equal, the inventory level per SKU declines rapidly (Simchi-Levi, 1999).

Centralized Control/Risk Pooling

Typical demand forecasting follows three principles: (1) the actual demand is a stochastic process and the demand forecast cannot be precise, (2) the longer the forecast horizon, the worse the forecast, and (3) aggregate forecasts are more accurate than disaggregate ones (Simchi-Levi et al., 2001). Logistic models have shown that centralized inventory control may improve demand forecasting and thereby reduce the stock-out probability. One approach is to consolidate scattered distribution sites to centralized distribution centers (CDC). As discussed earlier, according to the "square-root law" and by assuming a periodic review process in inventory control, we can reduce the optimal safety stock from $\sigma n\sqrt{L+r}$ in a decentralized distribution system to $\sigma\sqrt{n}\sqrt{L+r}$ in a centralized one, where *n* represents the number of identical distribution sites.

One major problem with CDC is the potential increase in transportation cost. As discussed, with the improvement in transportation technology and the deregulation in the transportation industry, transportation cost has been a less important factor in industrial location choice than before. Many firms in manufacturing industries, particularly those with high demand volatility and low unit delivering costs, such as consumer goods industries, have established CDCs to pool risk and reduce the total inventory (Simchi-Levi et al, 2000).

3.3 Summary

The total expected optimal inventory is a function of ten major variables: $E[INV]^* = F(n, D, C_o, C_h, C_p, C_B, z, \sigma, L, \tau)$. As the demand for customized products increases, industries such as apparel, food products, computer/electronics-manufacturing, and retail/wholesales have observed high-level product differentiation (Ginter and Sahling, 2004). As a result, the annual demand rate per SKU, *D*, has decreased in these industries. Also, with the advance of information technology, the ordering cost, C_o, has declined in most industries that have adopted computer-based management information systems. If we assume the purchase price, C_p, the holding cost, C_h, and the product's physical space requirement remain constant, given $\frac{\partial E[INV]^*}{\partial D} > 0$ and $\frac{\partial E[INV]^*}{\partial C_o} > 0$, the demand for inventory space per SKU is expected to decline in most industries if we only consider deterministic-cycle-stock. In addition, for the industries with products having short life cycles, such as apparel and computer/electronics-manufacturing, the increased customer service levels make the holding more costly than before because of the increased obsolescence cost. Given $\frac{\partial E[INV]^*}{\partial C_h} > 0$, the optimal inventory is also expected to decline.

At the same time, because of the intensified competition and rising demand for high-quality services, backorder cost, C_B, and required service level, z, have both increased in most industries. Given $\frac{\partial E[INV]^*}{\partial C_B} > 0$ and $\frac{\partial E[INV]^*}{\partial z} > 0$, the stochastic safety stock is expected to increase. Also, rapid technological advancement has increased demand volatility σ because of shortened product life cycles and increased product differentiations resulting from the rising demand for customization (Ginter and Sahling, 2004). Given $\frac{\partial E[INV]^*}{\partial \sigma} > 0$, the safety stock is also expected to increase.

Inventory levels and locations should vary by product and customer because of different product characteristics and customer requirements (Byrnes, 2003). Nonetheless, the total inventory is the sum of cycle stock and safety stock, and it is not clear whether the total inventory should have increased or decreased in most industries based on the theoretical analysis. Similarly, due to the competing forces of minimizing inventory costs that generally prefer centralized distribution centers versus improving service levels that usually require proximity to end customers, it is also unclear whether firms should have consolidated or dispersed their distribution facilities in their supply chains. Therefore, the theoretical impact of modern logistics on industrial location choice and property markets is ambiguous based on the fundamental logistic models. To derive the actual impact, I conduct empirical analyses in Chapters 4 and 5.

CHAPTER 4
EMPIRICAL ANALYSIS I: MODERN LOGISTICS AND INDUSTRIAL DISPERSION

As discussed earlier, supply-chain management (SCM) has been a core component in many manufacturing and distribution firms' business models. Firms in different industries have their specific product characteristics, demand patterns, and required service levels, so that they may prefer different logistic systems. The modern logistic systems adopted are not homogeneous across individual firms in manufacturing and distribution sectors. Also, good practice is known by many firms, but may not be adopted by every one. Thus, focusing on individual firms may generate limited information on the modern logistics' actual impact on industrial location choice and property markets. At a macro level, to test the hypothesis that modern logistics have been dispersing firms into certain regions and reducing the demand for industrial space per unit of industrial output, I conduct an analysis on industrial sectors from a regional perspective. Within an industrial sector or a sub-sector, given similar product characteristics, aggregately, we assume firms adopt relatively similar logistic systems.

Because the implementation of modern logistics directly or indirectly determine firms' location choice and industrial space demand, holding major macroeconomic variables constant, we expect that, for each industrial region and space market, it is the supply-chain configuration that fundamentally determines the demand for industrial space at the macro-level, and it is the change in inventory requirements that determines the demand for industrial space at the micro-level. Admittedly, the relationship may not be so straightforward and the actual demand may depend on many variables, but from an aggregate industrial perspective and at the regional level, the industrial real-estate stocks should adjust to their desired level gradually and the relationship holds in the long run. Actually, as previous empirical studies (TWR Research 2004) indicate, the supply of industrial space should usually be correlated closely with the demand. A major reason for the quick and smooth adjustment is the short time needed to construct industrial space. Another reason is the owner-occupied characteristic of the industrial market, which often does not involve lengthy negotiations before the construction.

Many firms now conduct SCM within a global context, so that I study the impact from a global perspective. Because of the data constraint, however, I perform empirical analyses and build econometric models using U.S. domestic data. The study period covers 16 years from 1989 to 2004 for industrial property markets and ten years from 1995 to 2004 for industrial inventory holdings. I choose such time horizons for two reasons, one is the data availability and the other is that ten years generally cover a full economic cycle and can avoid, or at least mitigate, the economy's cyclical effects.

I organize the empirical analysis as follows. In Section 4.1, I build concentration indices to study industrial consolidation/dispersion using data for 30 major U.S. industrial regions, which are also the 30 largest industrial real estate markets. Then, in Section 4.2, I study changing patterns of inventory holdings in 65 U.S. manufacturing, distribution, and retailing sectors by investigating 417 firms' annual 10-K reports to the U.S. Securities and Exchange

Commission (SEC) in the last decade. In Chapter 5, I study the impact of industrial mix and inventory turnover on the demand for industrial space using econometric analyses. I summarize the findings of the empirical analyses of Chapters 4 and 5 in Section 5.4.

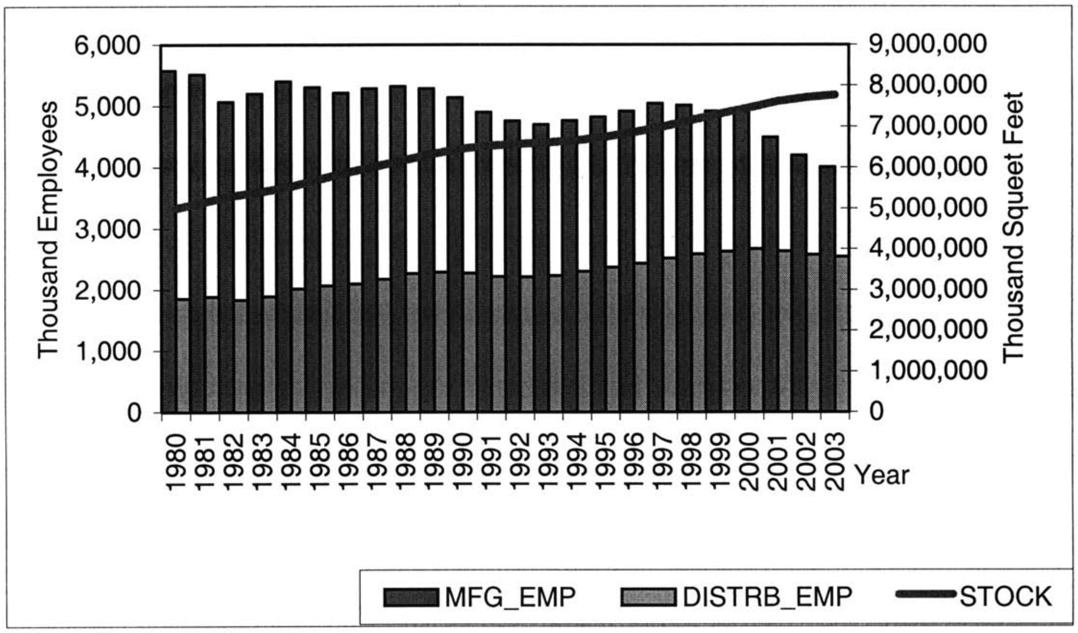
4.1. Industrial Location Choice: Consolidation vs. Dispersion

As described in Chapter 3, classic logistic theories suggest that, as the transportation cost becomes a less important factor in supply-chain design, dispersing manufacturing and distribution nodes can reduce the deterministic cycle inventory stocks by the square-root law. At the same time, however, the increased lead-time resulting from dispersion may require increased safety stocks. Also, as the power shifts to end customers, the rising demand for high service levels requires manufacturers, distributors, and retailers to locate their service outlets close to the market, pushing them to redesign their supply-chain networks. The interactions of these competing forces determine the location choice of manufacturing and distribution firms. In this empirical study, I use two variables to construct concentration/dispersion indices: industrial employment (EMP) and industrial real estate stocks (S).

I collect manufacturing and distribution employment data from the U.S. Census Bureau Metro Business Pattern database, which provides data on the total number of establishments and mid-March employment by detailed industry for all Metropolitan Statistical Areas (MSAs) and New England County Metropolitan Areas (NECMAs). As defined by the U.S. Office of Management and Budget, an MSA is made up of at least one large city (50,000 population or more), and includes the county or counties in which it is located. Adjacent and other nearby counties meeting certain criteria are also included in the MSA. I use NECMAs in this data series, which the Census provides for New England, as a county-based alternative to the usual city- and town-based New England MSA classifications. In this research, I focus on the 30 major industrial regions with the total industrial employment accounting for more than 40 percent of the total U.S. domestic. They are also the 30 largest industrial property markets with the total industrial real estate stocks comprising more than 40 percent of the U.S. total (Appendix 1).

I collect industrial real estate stock data from Torto Wheaton Research, which has maintained a property-level database for the last twenty years based primarily on the data collected by CB Richard Ellis, the largest U.S. real estate brokerage firm. The industrial property market consists of three major sectors: (1) manufacturing, (2) distribution, and (3) research and development (R&D). Generally, the real estate stock in the R&D sector accounts for a very small share in the total stocks. For instance, the industrial real estate stock in the 50 largest U.S. industrial markets in 1991 was about 6.2 billion square feet, of which manufacturing and distribution stocks each accounted for about 47 percent (2.9 billion square feet), while R&D and other types combined accounted for about six percent.

In the past two decades, the total employment in the U.S. manufacturing sector has been stable with a slight decline since 2000 (Figure 4-1 and Appendix 2). In contrast, the total employment in the distribution sector has increased by almost 37 percent since 1980. The total industrial real estate stocks in the 50 major U.S. industrial markets have risen steadily from 5.0 billion square feet in 1980 to 7.8 billion in 2003, or by about 56 percent. This implies that the increase in the demand for industrial space may be primarily due to the increase of demand in the distribution sector.



Data Sources: U.S. Census Bureau (2002) and Torto Wheaton Research (2004)
Note: MFG_EMP=Manufacturing Employment; DISTRB_EMP=Distribution Employment; Stock=Total Industrial Real Estate Stocks.

Figure 4-1.
Manufacturing and Distribution Employment and Total Industrial Real Estate Stocks, 1980-2003.

Noticeably, the correlation between distribution employment and total industrial real estate stocks is 0.97, which indicates an almost perfect co-movement between the two variables. In contrast, the correlation between manufacturing employment and total industrial real estate stocks was –0.82, showing that the two variables moved in the opposite directions. This finding suggests that the change in the distribution sector is the driving force underlying the increased demand for industrial space. In Table 4-1, I disaggregate the total real estate stocks into the manufacturing and the distribution stocks, and the correlation matrix shows consistent results.

Table 4-1.
Temporal Correlation Matrix between Employment and Demand for Industrial Space, 1980-2003

	E_mfg	E_dis	S_mfg	S_dis
E_mfg	1.000			
E_dis	-0.359	1.000		
S_mfg	-0.767	0.871	1.000	
S_dis	-0.760	0.874	0.999	1.000

Source: calculated by the author based on the U.S. Census Bureau (2002) and Torto Wheaton Research (2004) data
Notes: E_mfg=National Manufacturing Employment
E_dis=National Distribution Employment
S_mfg=National Industrial Property Stocks for Manufacturing
S_dis=National Industrial Property Stocks for Distribution

Thus, although the total manufacturing employment has decreased, both the total distribution employment and the demand for industrial space have increased. Essentially, the demand for industrial space is driven by two factors: (1) change in manufacturing output and distribution inventory and (2) efficiency in the industrial-space use. As shown in Appendix 3, from 1989 to 2004, manufacturing employment decreased by 24 percent, while the demand for industrial manufacturing space increased by 12 percent. The negative correlation between the two variables indicates that, during the past 16 years, manufacturing industries in the United States increased the demand for industrial space but reduced the demand for labor to fulfill their production, thereby becoming relatively less labor-intensive and more capital-intensive regarding the demand for physical real estate stocks. This may be partly due to the implementation of automation in manufacturing and distribution processes that generally require more working space than before, given the same production output. Also, the huge investment in information technology has improved the productivity and reduced the number of employees, given the same level of industrial output.

During the same period of 15 years, the distribution employment increased by about 12 percent, while the demand for distribution space increased by almost 30 percent, indicating that the elasticity of the space demand with regard to employment in the distribution sector is greater than two. If we assume that one unit of the increase in employment would incur two units in the increase in output, i.e., productivity has doubled, and given that inventory holding fundamentally determines the demand for industrial space, it seems that, as a whole, distribution firms hold more inventories, or need more inventory space, than before with the same level of industrial output. As shown in Table 4-2, for the elasticity of the demand for industrial space with regard to the employment, only three of the 30 major U.S. industrial markets observed an elasticity greater than one in the manufacturing sector, while 16 of the 30 markets observed the elasticity greater than one in the distribution sector. The aggregate national demand for industrial space with regard to the manufacturing employment was negative and inelastic (ε=-0.4). By comparison, the demand for distribution space with regard to the distribution employment was positively elastic (ε=2.3).

Table 4-2.
Elasticity of Employment to Demand for Industrial Space, 1989-2004

MSA Name	ε (EMP:S_mfg)	MSA Name	ε (EMP:S_dis)
Sacramento	1.9	Cleveland	9.8
Houston	1.5	Chicago	5.3
Riverside	1.3	San Jose	3.5
Los Angeles	-0.1	Detroit	3.1
Northern New Jersey	-0.1	Washington, DC	2.6
Seattle	-0.1	Atlanta	2.1
Philadelphia	-0.1	Portland	1.8
Boston	-0.2	San Diego	1.5
St. Louis	-0.2	Indianapolis	1.4
Cleveland	-0.2	Minneapolis	1.4
Baltimore	-0.3	Oakland	1.3
Miami	-0.3	Denver	1.3
Chicago	-0.4	Cincinnati	1.3
Fort Worth	-0.4	Sacramento	1.2
San Jose	-0.4	Dallas	1.2
Cincinnati	-0.5	Riverside	1.1
Kansas City	-0.7	Fort Worth	1.0
Denver	-1.0	Houston	1.0
Columbus	-1.0	Miami	0.9
Orange County	-1.0	Phoenix	0.9
Indianapolis	-1.3	Columbus	0.8
Detroit	-1.3	Orange County	0.5
Washington, DC	-1.4	Seattle	-0.5
Oakland	-1.5	St. Louis	-2.1
Dallas	-1.6	Northern New Jersey	-2.2
San Diego	-1.7	Baltimore	-4.8
Portland	-2.7	Los Angeles	-4.8
Minneapolis	-3.5	Philadelphia	-5.9
Phoenix	-4.4	Boston	-12.8
Atlanta	-5.4	Kansas City	-20.0
National	-0.4	National	2.3

Source: calculated by the author based on the Torto Wheaton Research Database
Notes: EMP=Employment; S_mfg=Manufacturing Real Estate Stock;
S_dis=Distribution Real Estate Stock

Thus, once again, the change in the distribution sector seems to be the major factor underlying the changes in the demand for industrial space. The high positive distribution-space demand elasticities of Cleveland and Chicago are probably because they are traditional heavy-industry bases and the intensified international competition and the rising demand for high-quality services may have increased the demand for inventory holdings. At the same time, increased use of automation in logistics may have improved productivity and reduced the demand for distribution workers. As a result, the demand for industrial space grew much faster than the employment and the market observed a highly elastic demand.

In summary, as SCM becomes the core component of manufacturing and distribution firms' business models, changes in logistic/distribution functions, such as the implementation of modern inventory control and supply-chain configuration, have been the driving force in the industrial space market. Technological and managerial improvements in the manufacturing sector, such as lean systems and total-quality management, had been adopted extensively by the late 1980s, and since then firms have been seeking new business strategies to reduce production/distribution costs and increase market shares. This is particularly true for U.S. manufacturing firms after they learned from Japanese firms' experience in production management in the 1980s. As a result, in both the manufacturing and distribution sectors, industrial location choice and the demand for industrial space have been gradually determined by firms' logistic functions and supply-chain requirements.

In order to evaluate the level of consolidation/dispersion of industrial space markets, I build concentration indices by employing three different types of indicators. The first one, the Herfindhal-Hirschman index, is simple and widely used in concentration studies. The concentration indicator H is given as:

$$H = \sum_i \left(\frac{s_i}{S}\right)^2$$

where s_i represents the total industrial real estate stocks or industrial employment in the i-th market and S represents the national total. The H index is the summation of the squares of individual markets' shares in terms of industrial space stocks or employment. It increases with the level of concentration and reaches its upper-bound of one with a maximum level of concentration and its lower-bound of zero with a minimum level of concentration.

The second index, the Theil entropy coefficient T, is defined as:

$$T = \sum_i (\frac{s_i}{S}) \log\left(\frac{s_i}{S}\right)$$

where s_i and S have the same definition as in the Herfindhal-Hirschman index. The main difference between the H and T indices is that the former is a convex function on the shares of industrial real estate stocks or employment, i.e., an increase in the index value accelerates as the share increases (the second-order derivative is greater than zero), whereas the latter is a concave function on the shares, i.e., an increase in the index value decelerates as the share increases (the second-order derivative is less than zero). The former is influenced more by the changes in the share of large regions/markets, whereas the latter is influenced more by the changes in the share of small regions/markets (Low et al., 1998).

A comparison of these two indices provides information on what kinds of regions/markets (relatively small or large in terms of the size of industrial real estate stocks or employment) dominated changes. For example, if T is relatively constant through time while H increases, then it indicates that the increase in concentration has mainly occurred within the group of regions/markets that have a large share of the total industrial real estate stocks or employment.

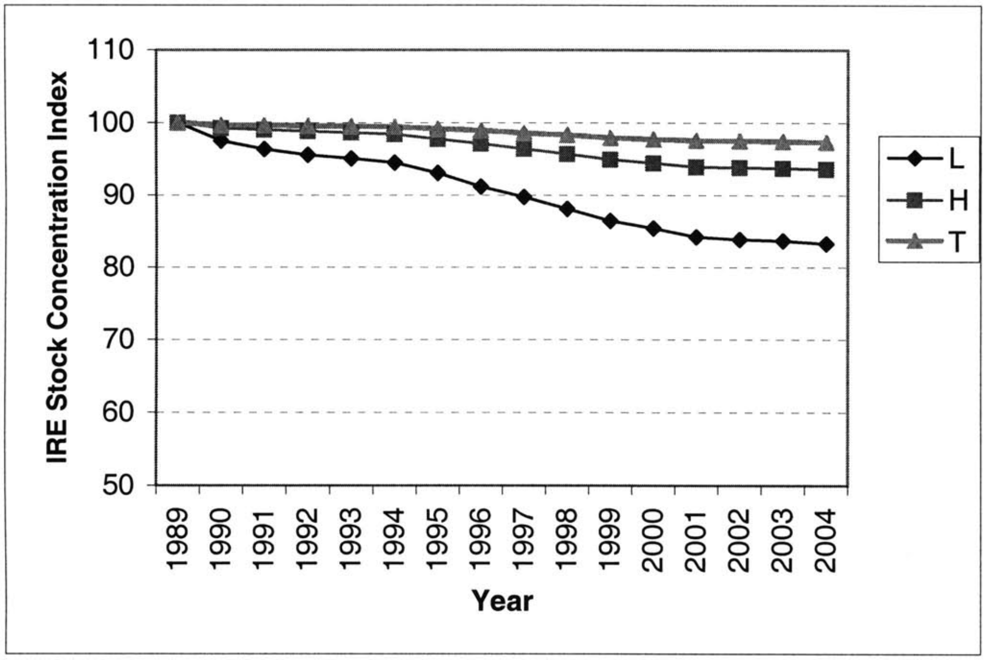
I also calculate a third index, Mean Logarithm deviation (L), to supplement the first two indices. The shortcoming of the first two indices is that they are sensitive to the change in the number of observations, i.e., the number of industrial markets in this research. For example, if at time zero there are two identical markets, then H would be 0.5; at time one, if the statistical sample consists of the same identical markets, then H would remain at 0.5, but if the sample includes an additional identical market, then H would be 0.33 although the concentration situation is the same. To overcome this type of sensitivity to the number of observations, I use the concentration index of the Mean-Logarithm deviation, defined as (Low et al. 1998):

$$L = \log\left(\frac{1}{n}\sum_i s_i\right) - \frac{1}{n}\sum_i \log(s_i).$$

where s_i has the same definition as in the first two indices.

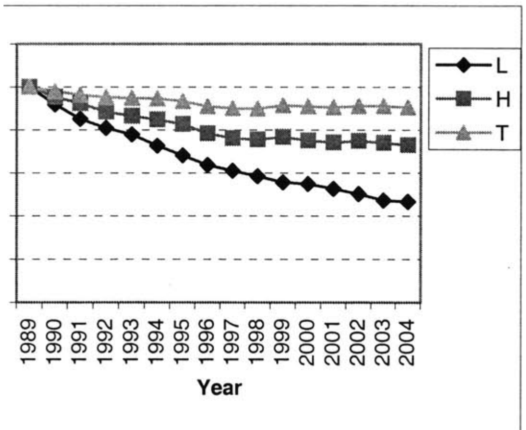
As shown in Figure 4-2, in total, the industrial space market has experienced continuous dispersion over the past 16 years. In Figures 4-3a, I show the three types of indices for manufacturing employment in the selected 30 U.S. industrial markets, normalized with the base-year (1989) value as 100 for comparison. Values of all three indicators decreased continuously throughout the study period, indicating a steady dispersion in the manufacturing industry as a whole. Thus, in general, firms in the manufacturing industries dispersed their production into individual markets. Similarly, distribution employment also dispersed continuously from 1989 to 2000 and has since stabilized (Figure 4-3b).

In the industrial-space market, the demand in the manufacturing sector has dispersed gradually since 1989 and the dispersion accelerated from 1997 (Figure 4-3c). The demand for the distribution space follows a similar trend, dispersing steadily during the 1990s and stabilizing after 2000 (Figure 4-3d).

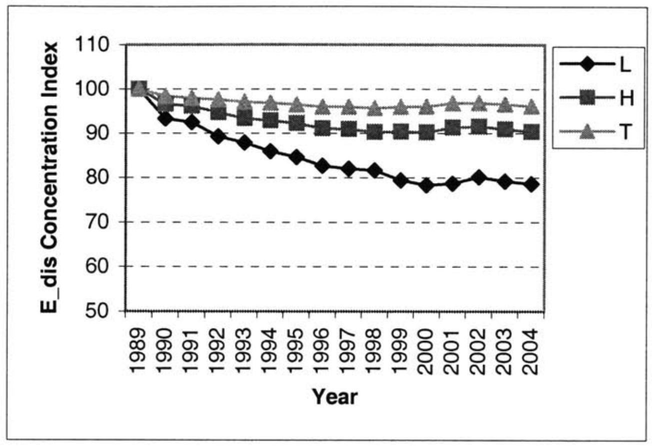


Source: calculated by the author based on the U.S. Census Bureau (2002) and Torto Wheaton Research (2004) data
Notes: H=Herfindhal-Hirschman Index; T=Theil Entropy Coefficient Index;
L=Mean Logarithm Deviation Index; IRE=Industrial real estate stocks

Figure 4-2.
Concentration Indices of Total Industrial Space



(a)



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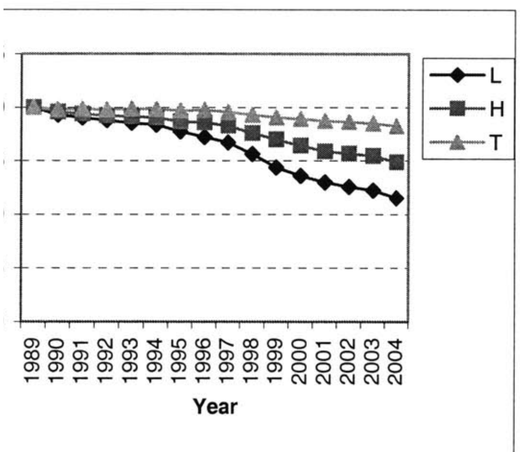
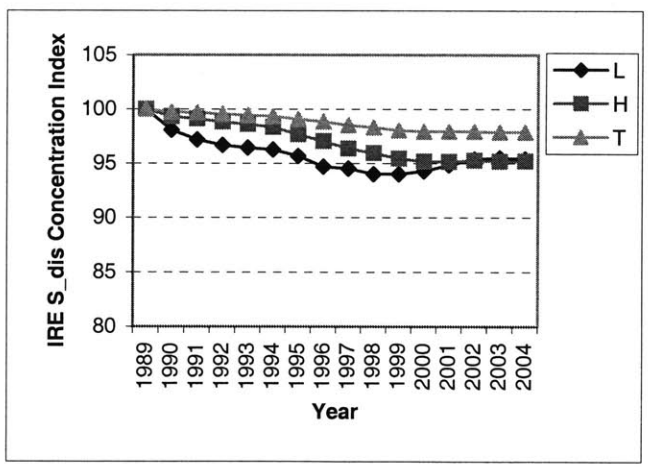


(c)



(d)

:alculated by the author based on the U.S. Census Bureau (2002) and Torto Wheaton Research (2004) data
=Herfindhal-Hirschman Index; T=Theil Entropy Coefficient Index; L=Mean Logarithm Deviation Index;
_mfg=Manufacturing employment; E-dis=Distribution employment; IRE=Industrial real estate stocks;
_mfg=Manufacturing space; S_dis=Distribution space

l-3 a, b, c, d.

tration Indices of Industrial Employment and Space

The co-movement of the industrial dispersion of manufacturing and distribution is also shown in Table 4-3, which lists the correlation coefficients between manufacturing and distribution employment and space demand. All the correlation coefficients are greater than 0.65, showing a strong co-movement trend.

Table 4-3.
Spatial Correlation Matrix between Employment and Demand for Industrial Space in 30 Major U.S. Industrial Regions, 1980-2003

	E_mfg	E_dis	S_mfg	S_dis
E_mfg	1.000			
E_dis	0.717	1.000		
S_mfg	0.651	0.805	1.000	
S_dis	0.667	0.827	0.730	1.000

Source: calculated by the author based on the U.S. Census Bureau (2002) and Torto Wheaton Research (2004) data
Notes: E_mfg=National Manufacturing Employment
E_dis=National Distribution Employment
S_mfg=National Industrial Property Stocks for Manufacturing
S_dis=National Industrial Property Stocks for Distribution

Thus, both the employment and the demand for space in manufacturing and distribution sectors have significantly dispersed. Such a continued industrial dispersion in the 1990s corresponded to the rapid economic growth during the same period. As discussed in Chapters 2 and 3, as SCM became a core component in manufacturing/distribution firms' business models, the competing forces of minimizing inventory-related costs and improving service levels constituted a pair of trade-offs in industrial-location choice and reshaped the physical patterns of the industrial space market from the 1980s. The above empirical results show that, as the competition for market shares intensifies and the power shifts to end customers, the dispersion economies accrued along supply chains have outstripped the agglomeration economies, and advances in modern logistics have enabled manufacturing and distribution firms to achieve the dispersion economies by locating facilities and employees close to individual markets.

Comparing the H and T indices, we find that H is always below T in all the above five index figures. This implies that the dispersion was mainly caused by the changes in large markets. As shown in Appendix 5, which ranks the markets by their manufacturing employment and the percentage change in employment during the past two decades, traditional large manufacturing regions, such as Chicago, St. Louis, Cleveland, Los Angeles, Northern New Jersey, Philadelphia, Baltimore, and Boston were losing shares in the total manufacturing employment; while smaller regions, such as Riverside, Sacramento, and Oakland, were gaining shares. Although the total manufacturing employment decreased by almost 40 percent over the study period, employment in some small markets, such as Riverside and Sacramento, increased in absolute value (47 percent and 15 percent, respectively).

Similarly, large industrial regions, such as St. Louis, Baltimore, Northern New Jersey, Philadelphia, and Los Angeles observed falling shares in the distribution employment (Appendix 6) even though the total distribution employment had increased by more than 20 percent in the study period. Small regions, such as Riverside, Sacramento, San Diego, and Fort Worth, observed large gains, generally by more than 25 percent. Appendices 7 and 8 show the consistent trend of the demand for industrial space in the manufacturing and distribution sectors.

The most active, or the fastest growing, industrial regions include Riverside, San Diego, Sacramento, Phoenix, and Atlanta. These regions experienced substantial increases in distribution employment and the demand for manufacturing and distribution space. Some of them (Riverside and Sacramento) even observed increases in manufacturing employment (compared to the declining trend in the country in general), indicating a sustained industrial growth in these regions. In addition, Orange County, Dallas, Fort Worth, and Indianapolis had also gained considerably. One possible reason may be that companies are increasingly dispersing their manufacturing and distribution locations across the country to achieve the economies of dispersion, locating their centralized distribution and manufacturing facilities in Northeast (Northern New Jersey), Southeast (Atlanta), Midwest (Indianapolis), South (Dallas/Ft Worth), and Southern California (Riverside). Another possible reason for such a trend may be that these growing regions are located on the global logistic routes, carrying goods shipped from Asia and Mexico that have been manufacturing bases supplying products to the U.S. manufacturing and retailing industries.

Comparing the H indices of employment in the manufacturing and distribution sectors also reveals the same trend that both employment and the demand for industrial space in the distribution sector are less dispersed than in the manufacturing sector. From the literature review in Chapter 2 and theoretical analysis in Chapter 3, we know that many firms have adopted the strategy of centralized distribution centers to pool risks, reduce total inventory holdings, and improve service levels. At the same time, many of them are employing the strategy of decentralized distribution centers to access local markets and increase market shares. The empirical results from the above analysis indicate that both the manufacturing and distribution sectors in the United States have dispersed in order to reduce transportation costs, quickly obtain local customer feedbacks, and achieve high service levels, while as a whole the distribution sector has been less dispersed than the manufacturing sector.

Also, by comparing the employment change and the space-demand change in individual markets, we find that the changes are not uniform across markets, implying that different industrial mixes in different markets may have ultimately determined the consolidation or dispersion of industrial space and, in turn, the demand for industrial space in each market. To derive the impact implications of modern logistics, I study the consolidation/dispersion effect in individual industrial sectors using the same three indicators. In addition to the simplicity and other merits, the three concentration indices have another desirable property: they are decomposable, which means that I can discompose each index based on sub-sectors' data and then compare them at the sub-sector level. Both the Herfindhal-Hirschman index (H) and the Mean-Logarithm-deviation index (L) are market-weighted concentration indices that an analyst can decompose according to the shares of total industrial real estate stocks or employment in each industrial sector.

I calculate these two indices using the 1998-2002 *County Business Patterns* data compiled by the U.S. Census Bureau. I tabulate the data series by industry as defined in the North American Industrial Classification System: United

States, 1997 (NAICS). As shown in Table 4-4, since 1998, five out of the nine manufacturing sectors, including (1) apparel, (2) paper/wood, (3) chemicals, (4) metal/nonmetallic minerals, and (5) machinery equipment, have not had a clear trend of consolidation or dispersion in terms of their manufacturing employment. The results are understandable for traditional manufacturing industries, such as paper/wood, chemicals, metal/nonmetallic minerals, and machinery equipment, which had experienced industrial restructuring, primarily consolidation, long before the study period. For the apparel industry, however, the result contradicts the expectation. It seems that, although some firms have been implementing quick-response systems or other modern logistics, which are expected to reduce total inventory holdings and improve service levels, the impact on industrial consolidation is not significant. It may be because many firms in the sector have moved their manufacturing businesses abroad so that the impact on domestic industrial consolidation becomes insignificant.

Firms in computer/electronics manufacturing, transportation equipment (primarily automobile and supporting auto-part manufacturing), and miscellaneous (including furniture and toys manufacturing) sectors have been dispersing their manufacturing throughout the study period. This implies that, instead of relying on industrial consolidation to reap the agglomeration economies, firms in these sectors are shifting production from existing large markets to smaller ones either to achieve the economies of proximity to individual markets or to reduce production costs, or both.

Table 4-4.
Sector-Based Consolidation and Dispersion Indices

	Manufacturing				**Food**			
Year	H (%)	L (%)	H Index	L Index	H (%)	L (%)	H Index	L Index
2002	15.3	9.7	97.4	90.2	18.6	13.6	107	116
2001	15.5	10.5	98.6	98.1	18.4	12.9	106	110
2000	15.6	10.5	99.2	97.6	18.4	12.6	106	108
1999	15.8	11.0	100.3	102.0	17.6	12.0	101	102
1998	15.8	10.7	100.0	100.0	17.4	11.7	100	100
	Decline				***Increase***			

	Apparel				**Paper/Wood**			
Year	H (%)	L (%)	H Index	L Index	H (%)	L (%)	H Index	L Index
2002	38.8	41.7	102	92	15.6	11.6	100	108
2001	35.6	40.3	94	89	15.8	11.6	102	107
2000	36.8	41.8	97	93	15.5	10.8	100	100
1999	36.9	42.0	97	93	15.8	11.4	102	106
1998	38.0	45.1	100	100	15.6	10.8	100	100
	NC				***NC***			

	Chemicals				**Metals/Nonmetallic**			
Year	H (%)	L (%)	H Index	L Index	H (%)	L (%)	H Index	L Index
2002	15.9	13.2	99	96	15.9	10.9	95	89
2001	16.1	13.2	100	96	15.6	10.8	93	89
2000	16.3	13.2	100	96	15.7	10.7	94	88
1999	16.3	12.9	101	94	16.7	12.1	100	100
1998	16.2	13.7	100	100	16.7	12.2	100	100
	NC				***NC***			

	Computer/Electronics				**Machinery Equipment**			
Year	H (%)	L (%)	H Index	L Index	H (%)	L (%)	H Index	L Index
2002	15.3	18.7	86	82	16.1	13.7	101	108
2001	16.6	21.6	94	95	15.8	13.8	100	109
2000	16.8	21.4	95	94	15.7	13.1	99	104
1999	18.4	23.9	104	105	15.9	12.8	100	101
1998	17.7	22.8	100	100	15.8	12.7	100	100
	Decline				***NC***			

	Transportation Equipment				**Miscellaneous**			
Year	H (%)	L (%)	H Index	L Index	H (%)	L (%)	H Index	L Index
2002	20.3	16.8	88	89	14.6	9.1	91	80
2001	20.6	17.6	90	93	15.0	9.6	94	85
2000	20.9	17.0	91	90	15.5	10.6	97	94
1999	21.4	17.4	93	92	15.4	10.0	97	89
1998	23.0	18.9	100	100	15.9	11.3	100	100
	Decline				***Decline***			

Source: calculated by the author based on the U.S. Census Data. Note: NC=Not Clear

Note that the food sector is the only sector that has a spatial consolidation, as shown by the increasing H and L indices in Table 4.4, which implies that improved technologies in food transport and centralized information management may have enabled firms in the food sector to consolidate their production. Continued consolidation in the industry implies that benefits accrued by both internal scale economies and external agglomeration economies have outstripped possibly increased shipping costs. The caveats of such simple factor analysis include the possible neglect of other influential factors and the unavoidable information loss in the data-aggregation process, but the empirical results here provide valuable directions for future research.

4.2. Industrial Inventories and Supply Chains

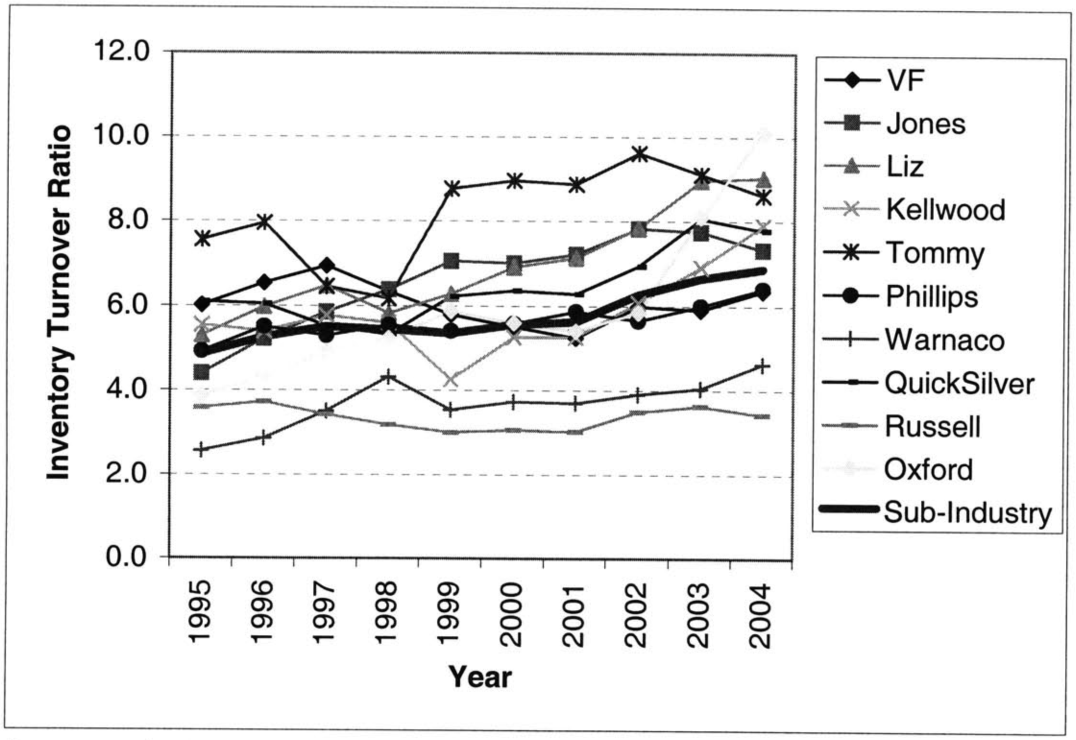
In Figures 4-3 a-d, I have shown the disparities between the dispersions of industrial employment and of industrial space. The difference is particularly pronounced in the distribution sector, in which the dispersion of the demand for industrial space has been significantly different from the dispersion of employment. In order to understand the actual impact of modern logistics on the demand for industrial distribution space, I investigate the change patterns of inventory holdings at the industrial-sector level and then compare individual supply chains.

I collect the firm-level data from the Standard & Poor's online Market Insight CompuStat database, selecting firms and aggregating the data based on the Global Industry Classification Standard (GICS), which is designed by the collaboration between Standard & Poor's and Morgan Stanley Capital International. It is an eight-digit system of classification that identifies a company according to its business activity. I study all the firms in the list of GICS sub-industry leaders, which include companies with revenue accounting for at least one percent of the total sub-industry. Totally, 129 sub-industries are listed in the database, and among them 50 are manufacturing, five are distribution, and ten are retailing. My study includes all the 65 sub-industries in the manufacturing, distribution, and retailing sectors.

Given the data availability for the past decade, I collected the inventory-related data of 417 companies in the 65 sub-industries from their audited annual 10-K reports to the U.S. Security and Exchange Commission (SEC) from 1995 to 2004. 10-K reports are the principle documents used by most public companies to disclose corporate information to shareholders. In general, for each sub-industry, the selected companies' total revenue accounts for at least 30 percent of the sub-industry's total revenue, so that the sample is large enough to track the change patterns of inventory holdings at the industrial-sector level. To mitigate the effect of inflation, I use the inventory-turnover (Inv-T) ratio, which is defined as annual sales divided by average inventories during that year as an indicator to study the changing patterns of inventory holdings for each firm and for aggregated sub-industries and industrial sectors.

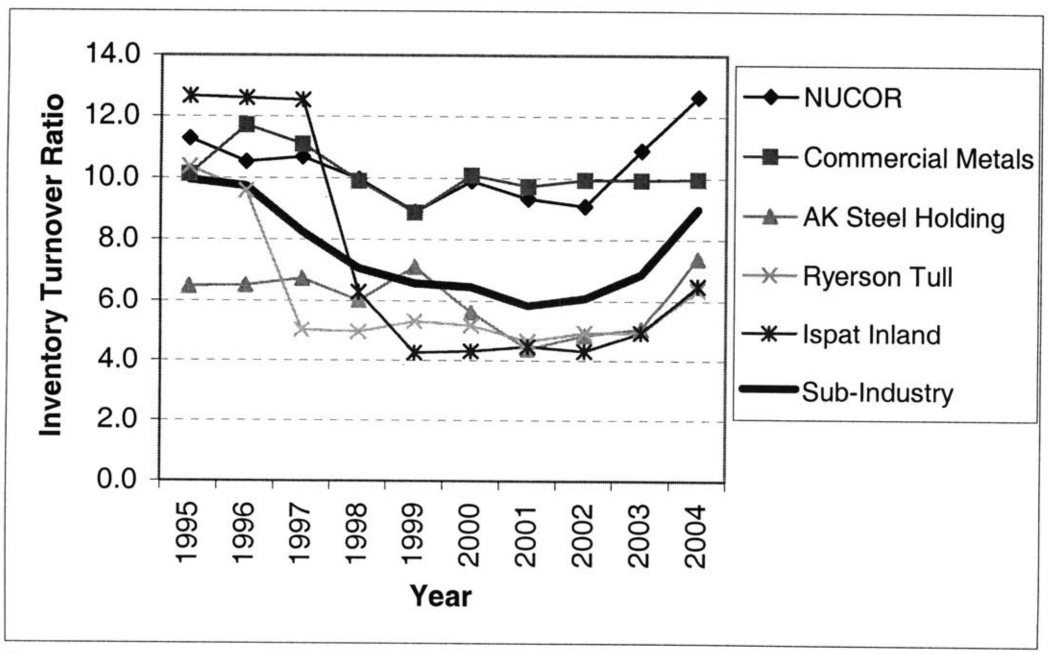
From the empirical results, I find that, in general, individual firms' Inv-T ratios within a sub-industry follow similar change patterns. For example, in the apparel industry (Figure 4-4), the largest ten U.S. firms' total revenue accounts for more than 40 percent of the industrial total; their Inv-T ratios show very similar change patterns to their sub-industry's. In the steel industry (Figure 4-5), Inv-T ratios of all the five major firms (given available data for the past ten years) in the United States follow a similar trend, decreasing in the late 1990s, stabilizing, and then slightly increasing from 2002, which is also consistent with their sub-industry's ratio. In the computer hardware industry (Figure 4-6), although Dell has enjoyed an unmatched rising Inv-T ratio, the three major firms, IBM, HP, and Dell, with their total revenue accounting for 55 percent of the total industry's, have all observed steadily increased turnover ratios. Similarly, in the computer/ electronics retail industry (Figure 4-7), the three major firms, BestBuy, CircuitCity, and RadioShack, with the total revenue accounting for 82 percent of the total industry's, also have very similar change patterns of Inv-T ratios.

Such similarities imply that firms in the same sub-industry may have adopted similar inventory control and SCM strategies to cope with the industry's specific production and distribution requirements. Because there is homogeneity in inventory holdings within a sub-industry, I aggregate the firm-level data to study the inventory control in a supply chain at a sub-industry level.



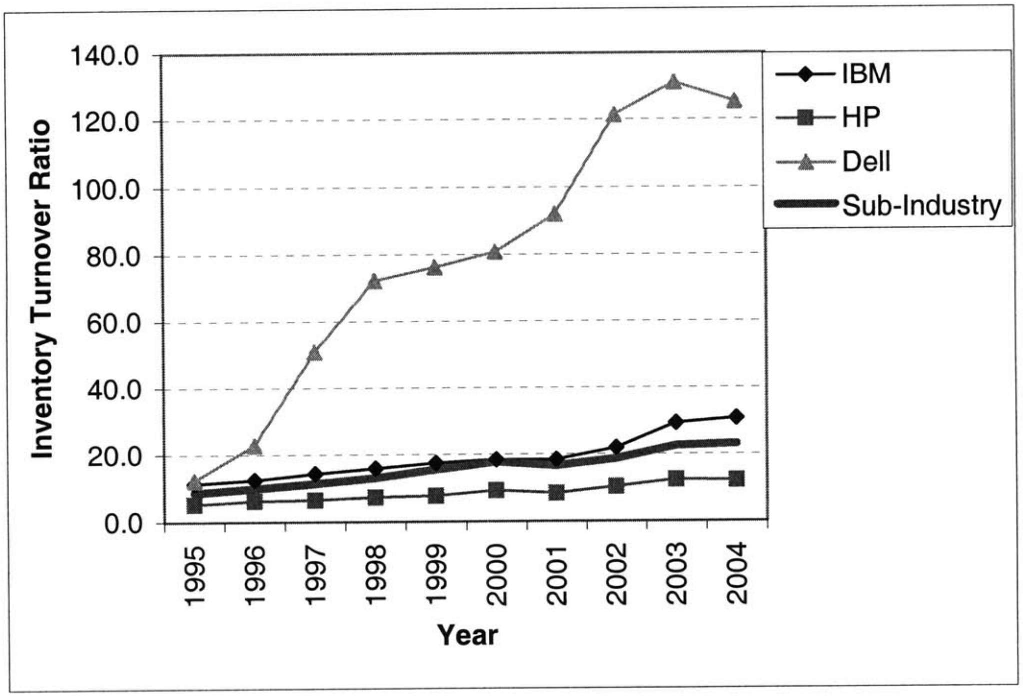
Source: calculated by the author based on the S&P CompuStat data

Figure 4-4.
Inventory-Turnover Ratios of Apparel Industry



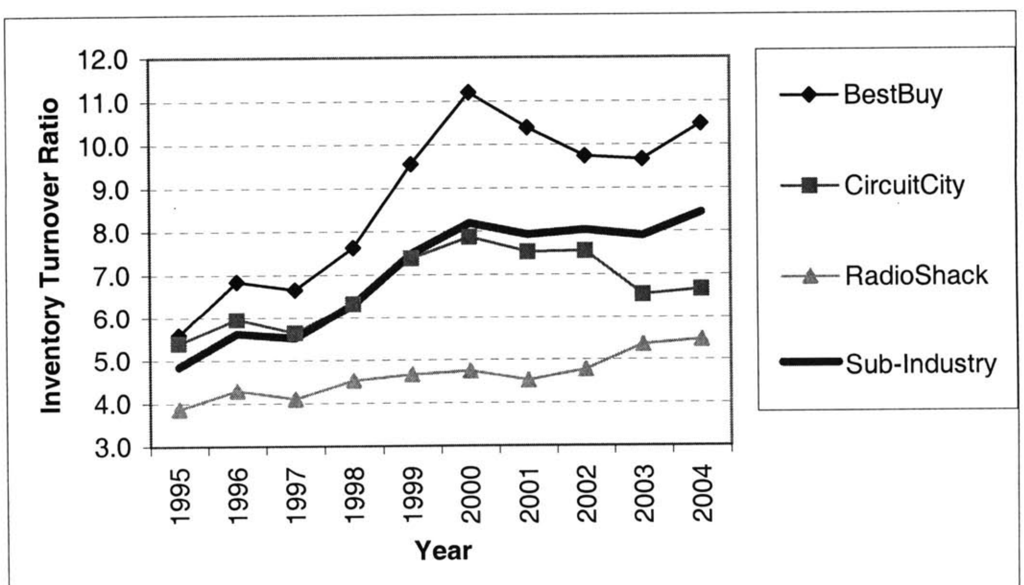
Source: calculated by the author based on the S&P CompuStat data

Figure 4-5.
Inventory-Turnover Ratios of Steel Industry



Source: calculated by the author based on the S&P CompuStat data

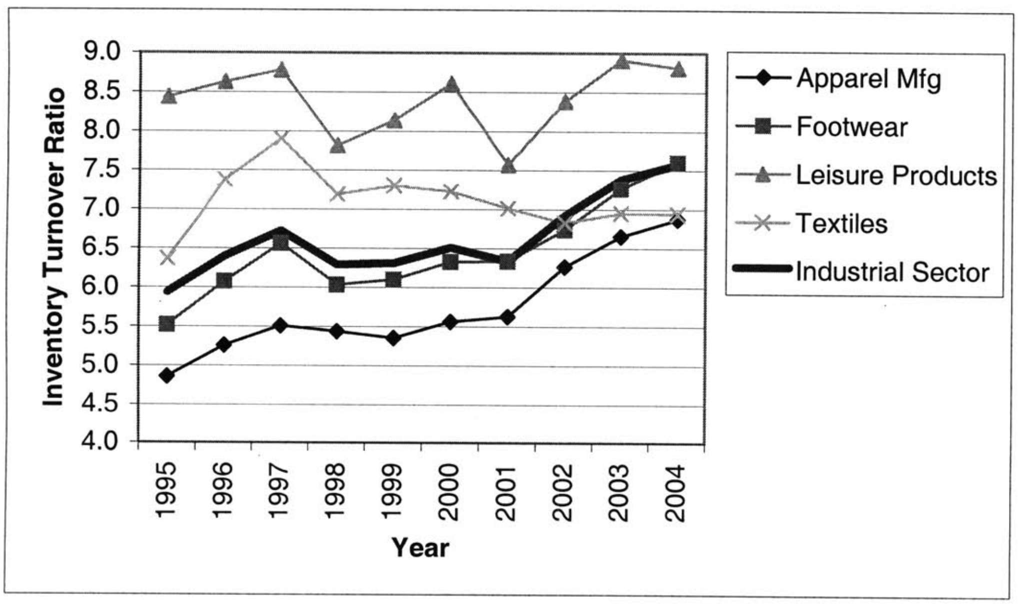
Figure 4-6.
Inventory-Turnover Ratios of Computer Hardware Industry



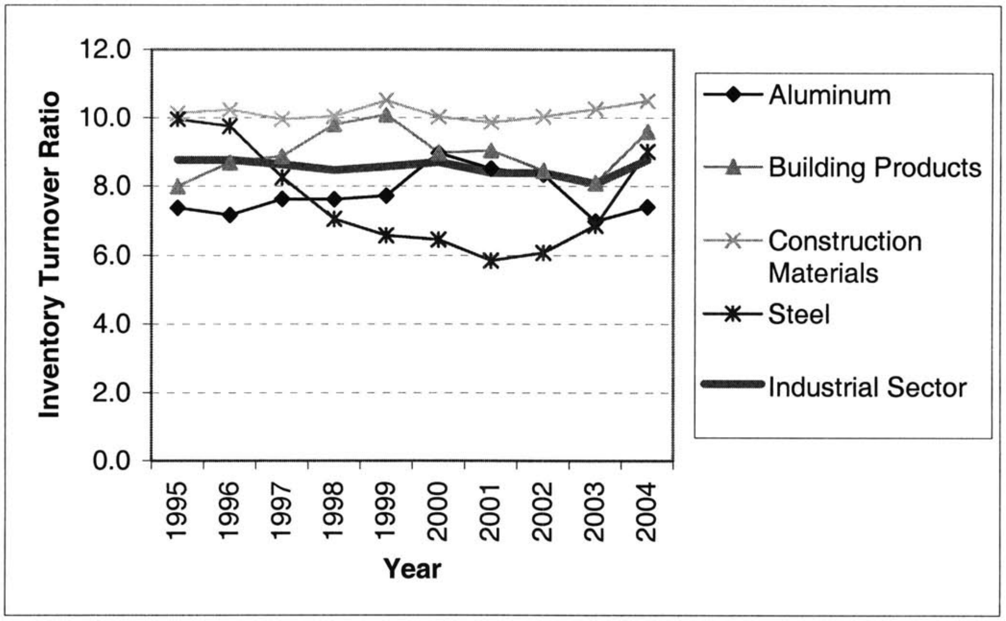
Source: calculated by the author based on the S&P CompuStat data

Figure 4-7.
Inventory-Turnover Ratios of Computer/Electronics Retail Industry

Furthermore, empirical results show that Inv-T ratios of sub-industries within an industrial sector also observe similar change patterns. For example, the apparel sector consists of four sub-industries: apparel manufacturing, footwear manufacturing, leisure products, and textiles (Figure 4-8). Inv-T ratios in the four sub-industries follow a similar change pattern as the apparel sector's. In particular, the sector's trend matches that of its two major sub-industries—apparel- and footwear-manufacturing. Similarly, in the metals/nonmetallic minerals sector (Figure 4-9), all the three sub-industries have fairly flat Inv-T ratio patterns over the past decade, which is consistent with the sector-wide index. In the next section, I aggregate the data at the industrial-sector level to conduct market studies.



Source: calculated by the author based on the S&P CompuStat data
Note: Mfg=Manufacturing
Figure 4-8.
Inventory-Turnover Ratios of Apparel Sector



Source: calculated by the author based on the S&P CompuStat data

Figure 4-9.
Inventory-Turnover Ratios of Metals/Nonmetallic Minerals Sector

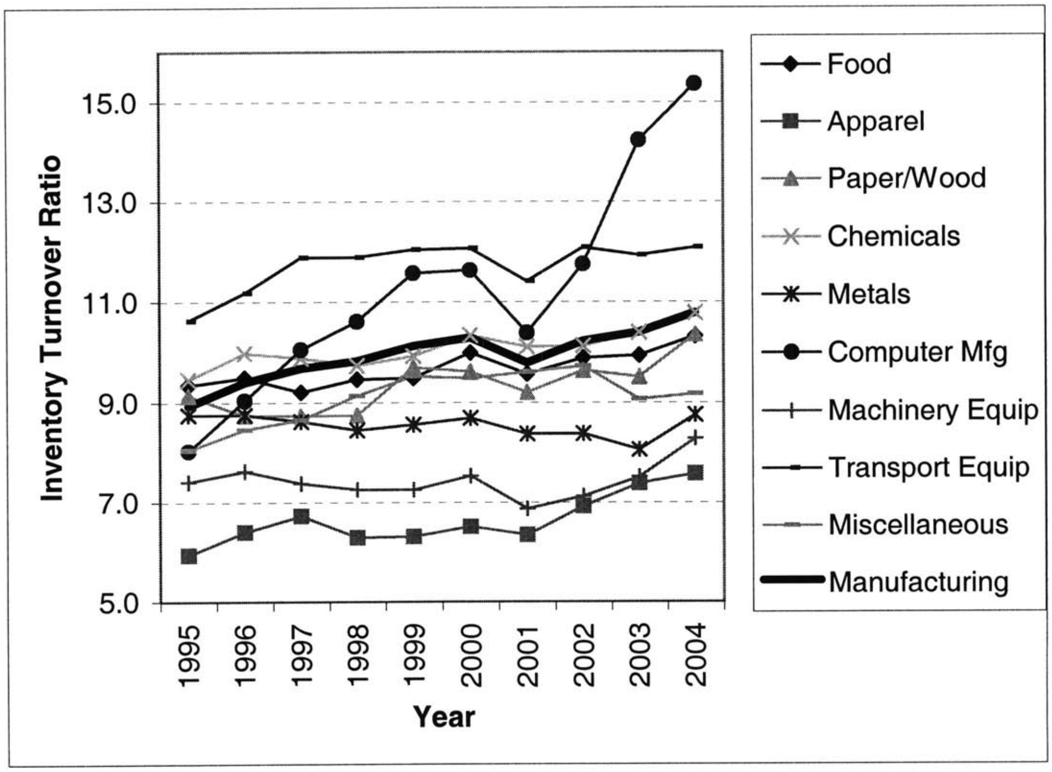
Since 1995, the aggregate manufacturing industry's Inv-T ratio has increased from 8.9 to 10.8, by 20.6 percent over the ten years and 2.1 percent compounded annually (Table 4-5). Overall, eight of the nine sectors, i.e., except for the metal products sector, have had an upward trend in their Inv-T ratios (Figure 4-10). Among these eight, the computer/electronics sector has the largest increase of more than 90 percent over the ten years. The Inv-T ratio in this sector increased from 8.0 to 15.4. Comparatively, the computer-hardware sub-industry consisting of IBM, HP, Dell, etc, has an increase from 8.6 to 22.9. During the same period, the apparel sector has the second largest increase of about 28 percent, and the remaining five, mainly traditional industries, including food, chemicals, machinery equipment, transportation equipment, and others (miscellaneous), have a less than 15 percent increase over the decade, i.e., a less than 1.5 percent increase compounded annually.

The only exception, the metals/nonmetallic-minerals sector observes almost no changes over the past ten years. This may be because firms in the metals sector do not have the financial capacity to restructure their supply chains or improve inventory controls as many firms, especially large steel firms, have been struggling through industrial consolidation to deal with increasing market competition and shrinking profit margins.

Table 4-5.
Inventory-Turnover Ratio and Percentage Change by Sector

	Inventory Turnover Ratios										Percentage Change	
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total	Annual
Computer Mfg	8.0	9.0	10.1	10.6	11.6	11.6	10.4	11.7	14.2	15.4	91.1%	7.5%
Apparel	5.9	6.4	6.7	6.3	6.3	6.5	6.3	6.9	7.4	7.6	27.6%	2.7%
Chemicals	9.5	10.0	9.9	9.7	9.9	10.3	10.1	10.1	10.4	10.8	13.9%	1.5%
Miscellaneous	8.1	8.5	8.7	9.1	9.5	9.5	9.6	9.7	9.1	9.2	13.9%	1.5%
Paper/Wood	9.1	8.7	8.7	8.7	9.7	9.6	9.2	9.6	9.5	10.3	13.3%	1.4%
Transport Equip	10.6	11.2	11.9	11.9	12.0	12.1	11.4	12.1	11.9	12.1	13.7%	1.4%
Machinery Equip	7.4	7.6	7.4	7.3	7.3	7.5	6.9	7.1	7.5	8.3	11.8%	1.3%
Food	9.3	9.5	9.2	9.5	9.5	10.0	9.6	9.9	9.9	10.3	10.4%	1.1%
Metals	8.8	8.8	8.6	8.5	8.6	8.7	8.4	8.4	8.1	8.8	0.0%	0.0%
Manufacturing	*8.9*	*9.4*	*9.7*	*9.8*	*10.1*	*10.3*	*9.8*	*10.2*	*10.4*	*10.8*	*20.6%*	*2.1%*
Distributors	*7.5*	*8.0*	*8.3*	*8.4*	*9.3*	*9.1*	*9.0*	*9.0*	*9.5*	*10.3*	*37.8%*	*3.6%*
Retailers	*6.5*	*7.0*	*7.2*	*7.3*	*7.9*	*7.9*	*8.2*	*8.5*	*8.4*	*8.8*	*34.0%*	*3.3%*

Source: computed by the author based on the S&P CompuStat database (2005)
Note: Mfg=Manufacturing; Equip=Equipment



Source: computed by the author based on the S&P CompuStat database (2005)
Note: Mfg=Manufacturing; Equip=Equipment

Figure 4-10.
Inventory-Turnover Ratio by Industrial Sector

In addition, the aggregate distribution sector and the aggregate retailing sector have both observed upward trends of Inv-T ratios, increasing by 38 percent and 34 percent, respectively, over the ten years and 3.6 and 3.3 percent per annum (Table 4-5). Thus, except in the metals/nonmetallic minerals sector, firms in almost all the other sectors have increased their Inv-T ratios. As discussed in Chapters 2 and 3, the positive outcomes are, more or less, achieved by the implementation of more efficient inventory control and supply-chain management. For example, the results show the efficacy of modern logistics in the apparel sector (Table 4-5). As discussed earlier, quick-response systems, centralized information management, data sharing, and risk-pooling strategies all helped firms in this sector to improve their overall logistical functions and, as a result, the sector enjoyed an average 2.9 percent annual increase in its Inv-T ratio.

Table 4-6.
Annual Percentage Change of Inventory-Turnover Ratio by Sector

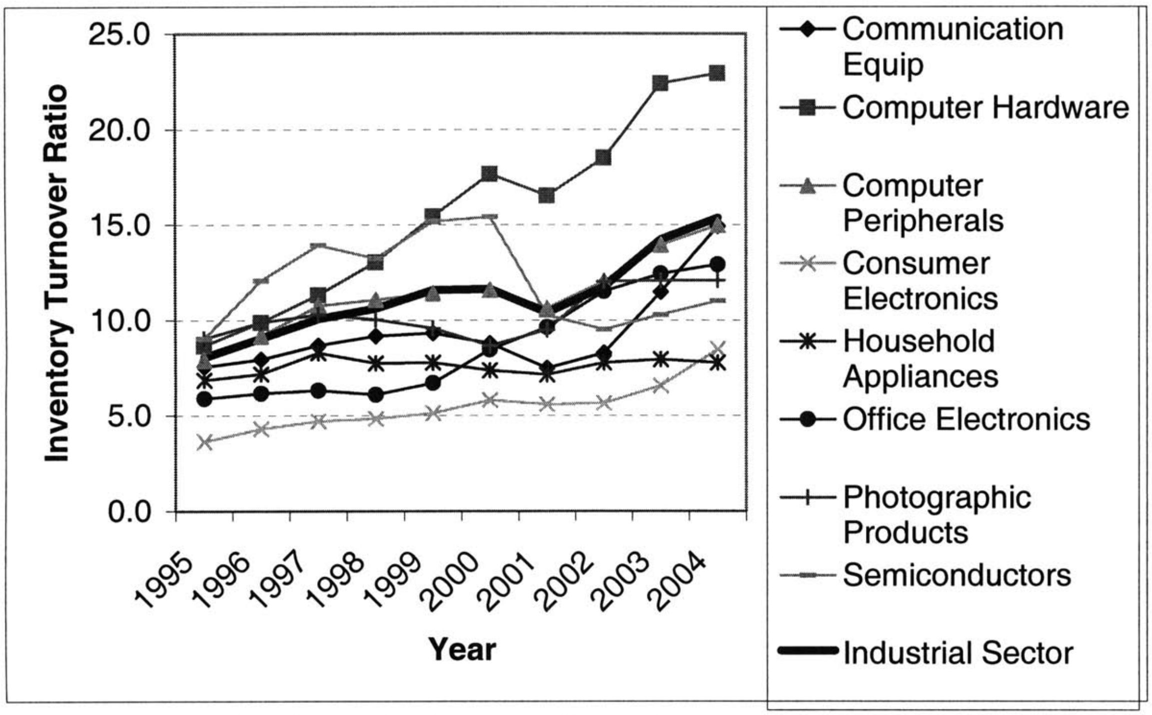
	1996	1997	1998	1999	2000	2001	2002	2003	2004	AVE	STDEV	t-stat
Computer Mfg	12	11	6	9	1	-11	13	21	8	7.8	8.9	2.76 *
Apparel	8	5	-7	0	3	-3	9	7	3	2.9	5.1	1.77
Paper/Wood	-4	0	0	11	-1	-4	5	-1	9	1.5	5.4	0.89
Chemicals	6	-1	-2	2	4	-2	0	3	4	1.5	2.7	1.73
Transport Equip	5	6	0	1	0	-5	6	-1	1	1.5	3.8	1.24
Miscellaneous	5	2	6	4	0	1	1	-7	1	1.5	3.7	1.30
Machinery Equip	3	-3	-2	0	4	-9	4	6	10	1.4	5.6	0.79
Food	2	-3	3	0	5	-4	3	1	4	1.1	3.1	1.16
Metals	0	-2	-2	1	2	-4	0	-4	9	0.1	3.8	0.05
Manufacturing	*5*	*3*	*2*	*3*	*2*	*-5*	*4*	*2*	*4*	*2.1*	*2.9*	*2.32 **
Distributors	*7*	*3*	*2*	*10*	*-2*	*-1*	*0*	*5*	*9*	*3.7*	*4.4*	*2.68 **
Retailers	*6*	*3*	*2*	*7*	*1*	*3*	*4*	*-2*	*5*	*3.3*	*2.7*	*3.92 **

Source: computed by the author based on the S&P CompuStat database (2005)
Notes: Unit is percentage changed, except for the t-stat;
Mfg=Manufacturing; Equip=Equipment;
AVE=Average Annual Change; STDEV=Standard Deviation of Annual Change;
T-Test Null Hypothesis: Annual Change=0;
* indicates that the change is statistically significant at the 95% confidence level.

The increase of the Inv-T ratios in the three aggregate sectors, i.e., manufacturing, distribution, and retail (Table 4-6), have all passed the statistical test (with a t-statistic greater than 1.83), indicating that their annual increases are significantly different from zero at the 95 percent confidence level. For the nine non-aggregate manufacturing sectors, however, only the computer/electronics sector passes the statistical test; all the other eight sectors' average annual change cannot reject the hypothesis of being zero. This can be due to the limited data, which only cover ten years. Nonetheless, at the most aggregate level, firms in the manufacturing, distribution, and retailing sectors have successfully reduced their inventory holdings; most sub-sectors have observed improved inventory controls, but only the computer/electronics sector has significantly increased its sector-wide Inv-T ratio.

Among the nine manufacturing sectors, the computer/electronics sector has the largest annual inventory-turnover growth of about 7.5 percent and the total growth during the ten years is more than 90 percent. This sector comprises the sub-industries of communication equipment, computer hardware, computer peripherals, consumer electronics, household appliances, and semiconductors. I included more than 50 firms in the research sample, including Motorola, Cisco, IBM, HP, Intel, AMD, Xerox, Eastman Kodak, Whirlpool, EMC, Lexmark, and some relatively small firms. The Inv-T ratio in the computer/electronics sector dropped by 11% from 2000 to 2001, the IT-bubble-burst period (Figure 4-11). Other than that, the Inv-T ratios increased continuously in the sector and its sub-sectors. The only exception is the household-appliances sub-industry, which observes a flat line. In the United States, this is a relatively mature industry compared to the sector's other sub-industries, such as computer hardware and communication equipment. Competition from low-labor-cost countries, such as China, has driven down the margin.

The underlying reason for the sector's exceptional performance may include many. As discussed in Chapters 2 and 3, many computer/electronics firms, with their unparalleled advantage in information technology (IT), have implemented advanced inventory control systems and SCM strategies, such as centralized management information systems, internet-based business-to-customer (B2C) and business-to-business (B2B) models, and advanced supply-chain partnership. All these may contribute to the improved inventory management of the sector.



Source: computed by the author based on the S&P CompuStat database (2005)

Figure 4-11.
Inventory-Turnover Ratios in Computer/Electronics Sector

It is noticeable that, across industrial sectors, the changes of Inv-T ratios are highly correlated (Table 4-7). Except for the metals/nonmetallic-minerals sector, most of the other eight sectors' Inv-T ratios have observed a correlation coefficient with another sector of no less than 0.5. This implies that the improvement of inventory control has been ubiquitous in most manufacturing industries and, as a result, U.S. manufacturing firms, except in the metals/nonmetallic-minerals sector, have reduced inventories they hold given the same level of industrial output.

Table 4-7.
Correlation Matrix of Inventory-Turnover Ratios of Industrial Sectors

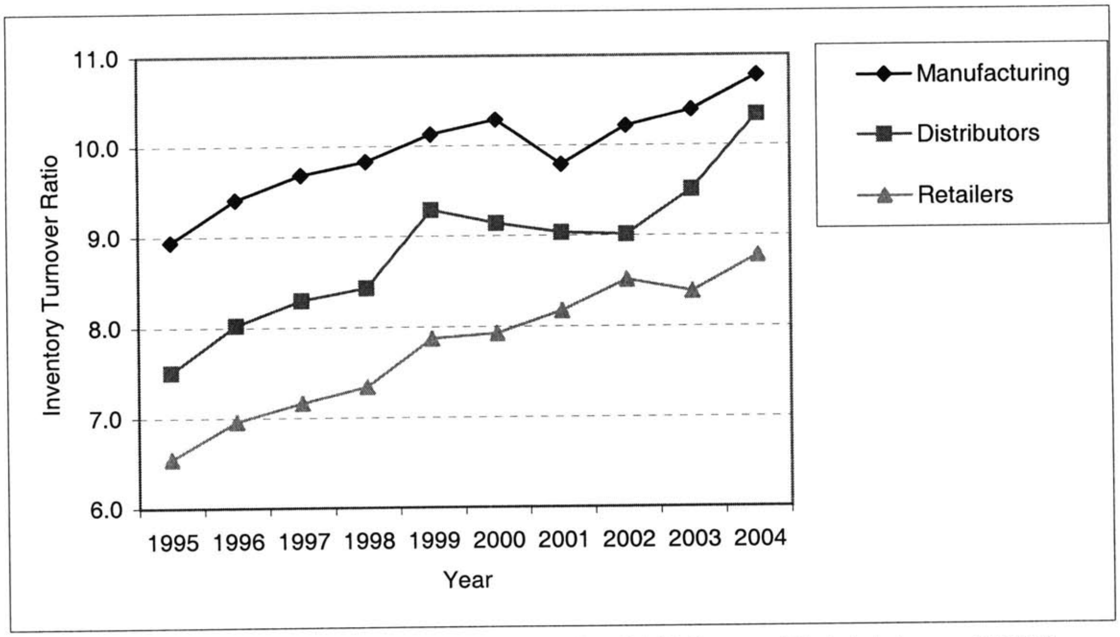
	Food	*Apparel*	*Paper*	*Chemicals*	*Metals*	*Computer*	*Machinery*	*Transport*	*Misc*
Food	1.0								
Apparel	0.8	1.0							
Paper	0.8	0.6	1.0						
Chemicals	0.9	0.9	0.7	1.0					
Metals	-0.1	-0.3	0.0	-0.2	1.0				
Computer	0.8	0.9	0.8	0.9	-0.4	1.0			
Machinery	0.6	0.6	0.5	0.6	0.5	0.5	1.0		
Transport	0.5	0.6	0.5	0.6	-0.3	0.7	0.1	1.0	
Misc	0.5	0.3	0.5	0.5	-0.4	0.5	-0.3	0.7	1.0

Source: computed by the author based on the S&P CompuStat database (2005)
Notes: Paper=Paper/Wood; Metals=Metals/Nonmetallic Minerals;
Computer=Computers/Electronics Manufacturing;
Transport=Transportation Equipment; Misc=Miscellaneous.

Regarding the supply chain, at the most aggregate manufacturing-distribution-retail level, the Inv-T ratio has increased significantly in all the three sectors, although the magnitudes are different. The distribution sector has performed the best with the annual Inv-T ratio increased by 3.6 percent; the Inv-T ratio in the retailing sector has an annual increase rate of 3.3 percent; the manufacturing sector has the lowest growth rate of 2.1 percent per annum.

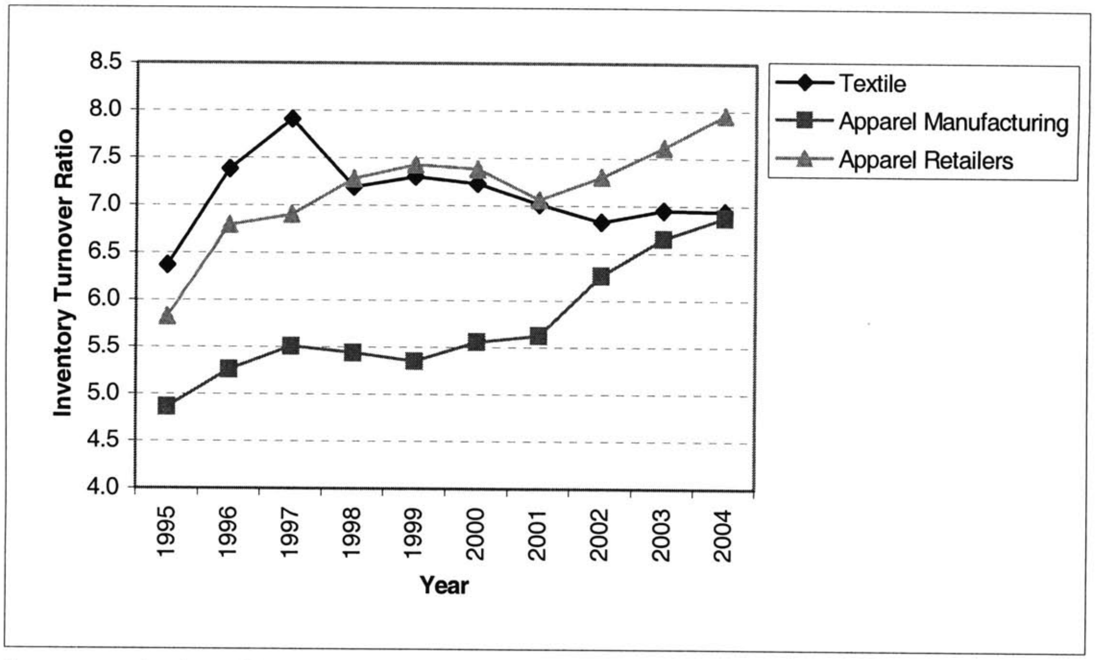
Given the homogeneity of inventory-change patterns within an individual sub-industry as discussed earlier, I use aggregate sub-industry data to investigate interactions among the players of industry-level supply chains. Some economists and management scientists (e.g., Weiss 2002, Masters 2003) suggest that, although advanced inventory control and sophisticated SCM have improved physical goods flow and information flow, dominant manufacturers with high negotiation power may have shifted their inventories, usually the safety stock, to upstream suppliers or downstream distributors, so that, from a supply-chain perspective, their gains in inventory reductions or service-level improvement are at the cost of their upstream suppliers and/or downstream customers. It is difficult, however, to test this hypothesis by studying individual firms because individual firms often have many suppliers and customers, and each supplier or customer may also have many suppliers and customers in their own supply chains. In addition, such business information is often confidential, and firms are usually reluctant to disclose it. Moreover, studies on specific firms often provide only limited information on general impact of modern logistics. Therefore, in order to test this hypothesis, I study seven industrial supply chains using aggregate sub-industrial data.

First, I study the manufacturing-distribution-retail supply chain at the most aggregate level. As discussed earlier, all the three sectors' Inv-T ratios have increased significantly over the past ten years. It is interesting to notice that the three upward curves follow very similar patterns (Figure 4-12). Manufacturers hold the least inventory given the same industrial output; distributors hold more while retailers hold the most, but, over the past decade, firms in all three sectors seem to have improved their inventory controls, and firms in the distribution sector have improved most significantly. Thus, the results show that the gains in the manufacturing sector are not necessarily at the expense of its downstream sectors. Modern logistics have enabled all the players in a supply chain to coordinate effectively and reduce their inventories simultaneously.



Source: calculated by the author based on the S&P CompuStat database (2005)
Figure 4-12.
Inventory-Turnovers in Manufacturing-Distribution-Retail Chain

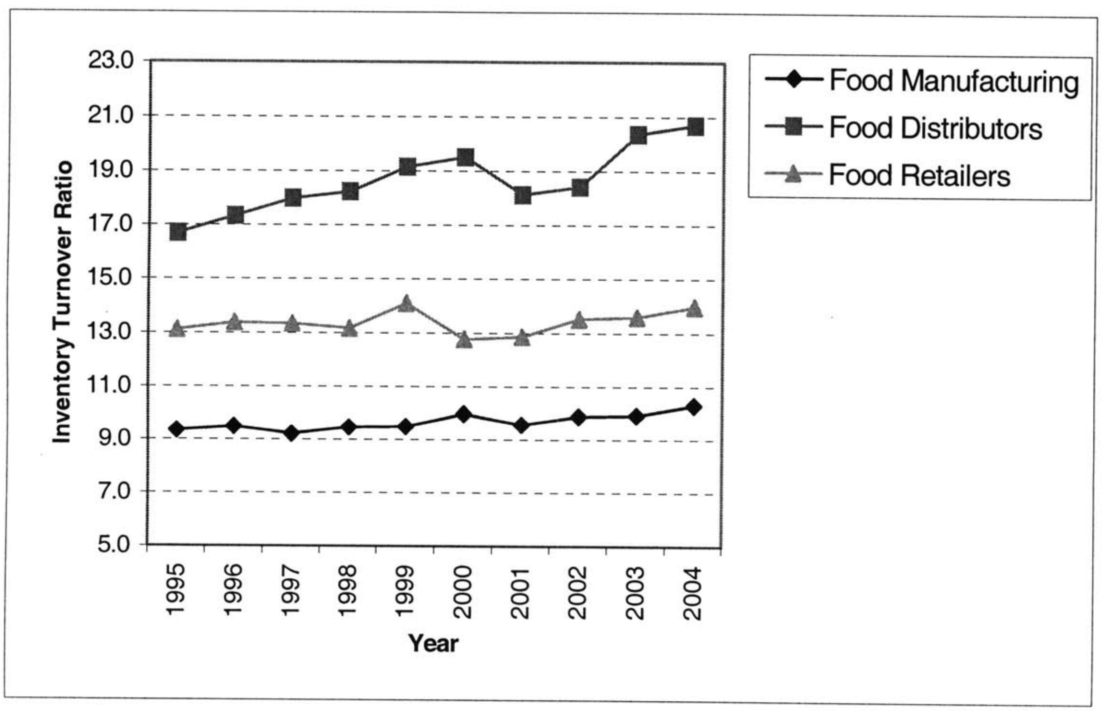
Second, I study the textile-apparel manufacturing-apparel retail chain. The supplier, the textile sector, has a different inventory-turnover change pattern from the apparel manufacturing and retail over the last decade (Figure 4-13). Because the textile sector is also the supplier of other manufacturing sectors, the relationship between apparel manufacturing and retail deserves more attention. The observed increased turnover ratios in both sectors lead to the same conclusion for the aggregate manufacturing-distribution-retail chain: the gains in upstream suppliers are not necessarily at the expense of downstream customers. Then, I study the food manufacturing-distribution-retail chain and the computer/electronics manufacturing-distribution-retail chain. Both show the similar trend of the three sub-sectors' inventory turnovers (Figures 4-14 and 4-15).



Source: calculated by the author based on the S&P CompuStat database (2005)

Figure 4-13.

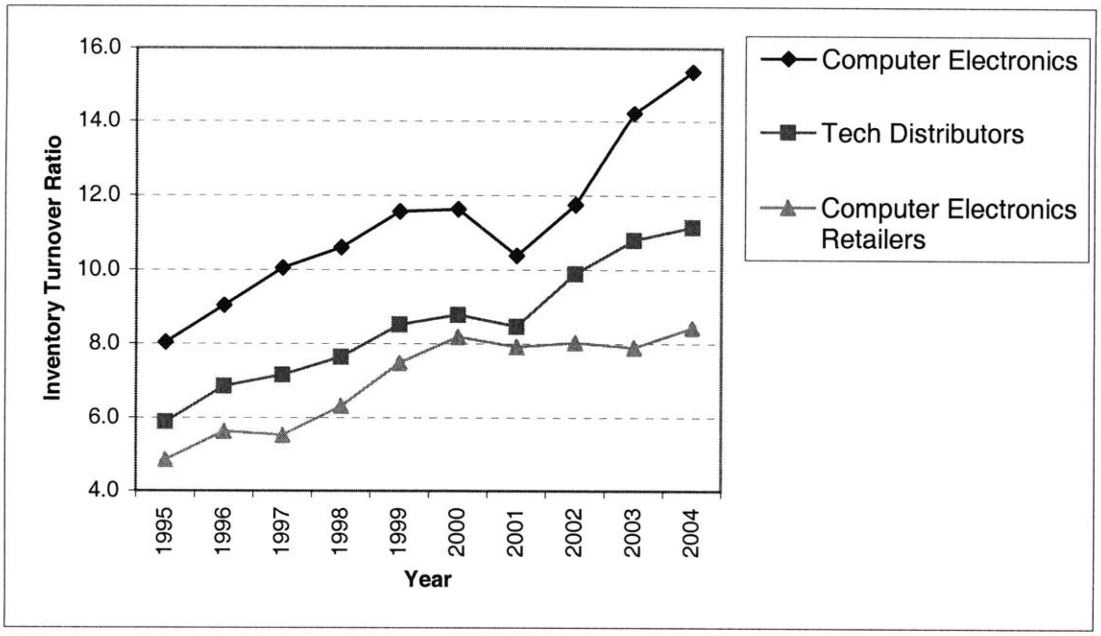
Inventory-Turnovers in Textile-Apparel Manufacturing-Apparel Retail Chain



Source: calculated by the author based on the S&P CompuStat database (2005)

Figure 4-14.

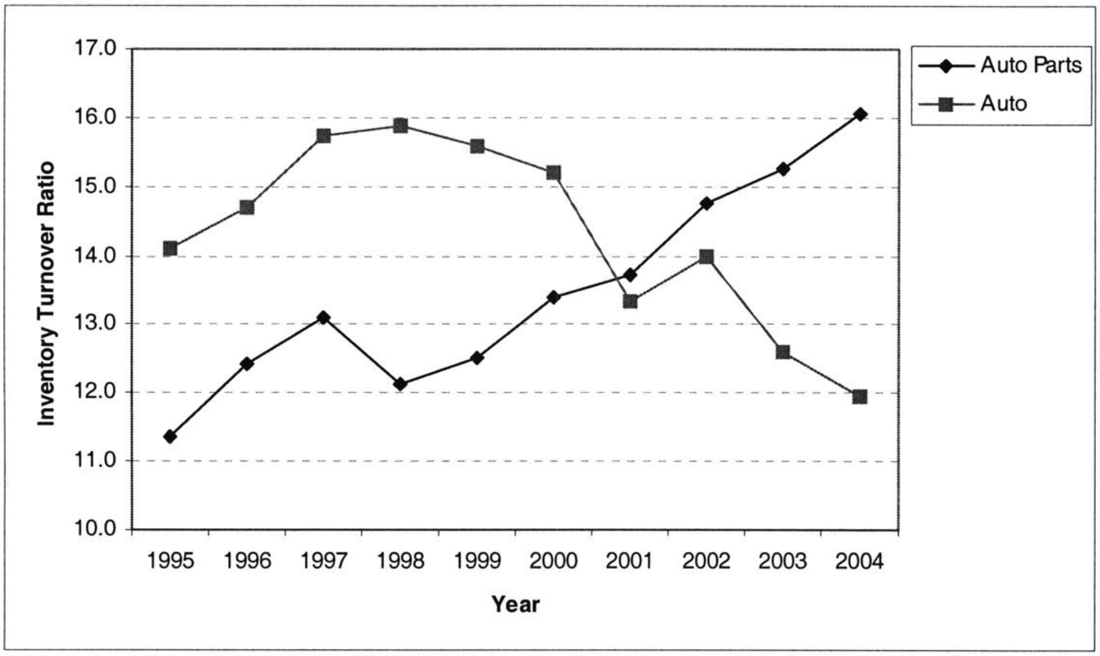
Inventory-Turnovers in Food Manufacturing-Distribution-Retail Chain



Source: calculated by the author based on the S&P CompuStat database (2005)

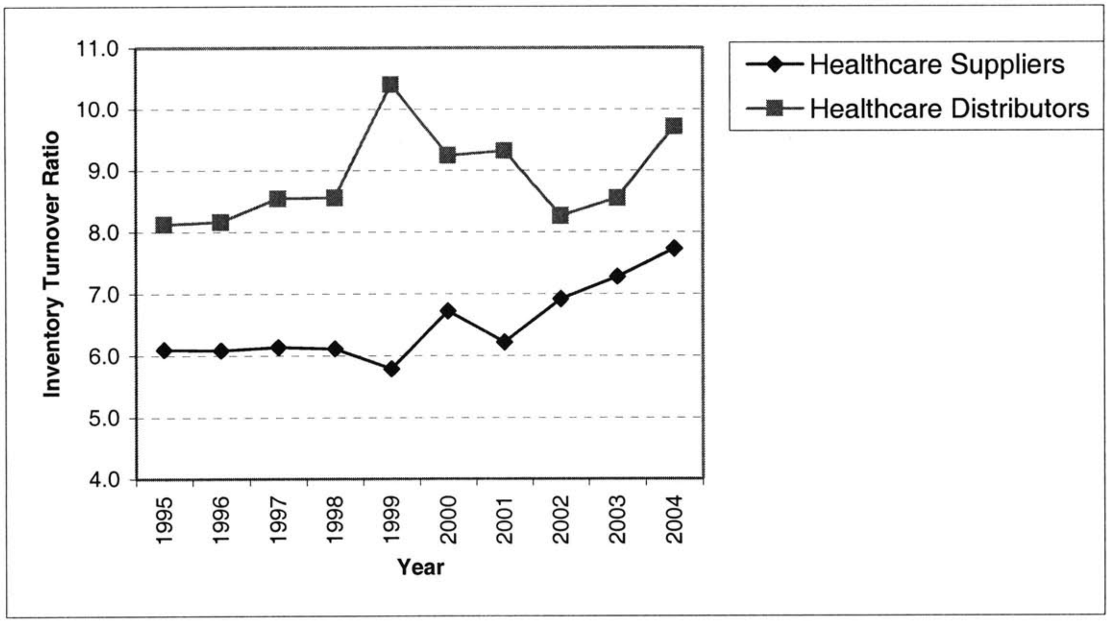
Figure 4-15.
Inventory-Turnovers in Computer/Electronics Manufacturing-Technology Distribution-Computer/Electronics Retail Chain

In the automobile supply chain, I focus on the auto parts-auto manufacturing chain. While the Inv-T ratio of the auto-parts sector increased, auto manufacturers observed a decreased turnover ratio (Figure 4-16), which contradicts the traditional wisdom that automakers have relatively large negotiation power compared to their component suppliers in the supply chain, and component suppliers have to increase inventories as automakers reduce inventory holdings. The empirical results show the opposite, implying that automakers might not have consolidated power as previously thought and, instead, their component suppliers had effectively used modern logistics, such as established centralized distribution centers, postponed product customization, and implemented advanced information technologies to share information and pool risks, thereby reducing inventories without sacrificing service levels.



Source: calculated by the author based on the S&P CompuStat database (2005)
Figure 4-16.
Inventory-Turnovers in Auto Parts-Auto Manufacturing Chain

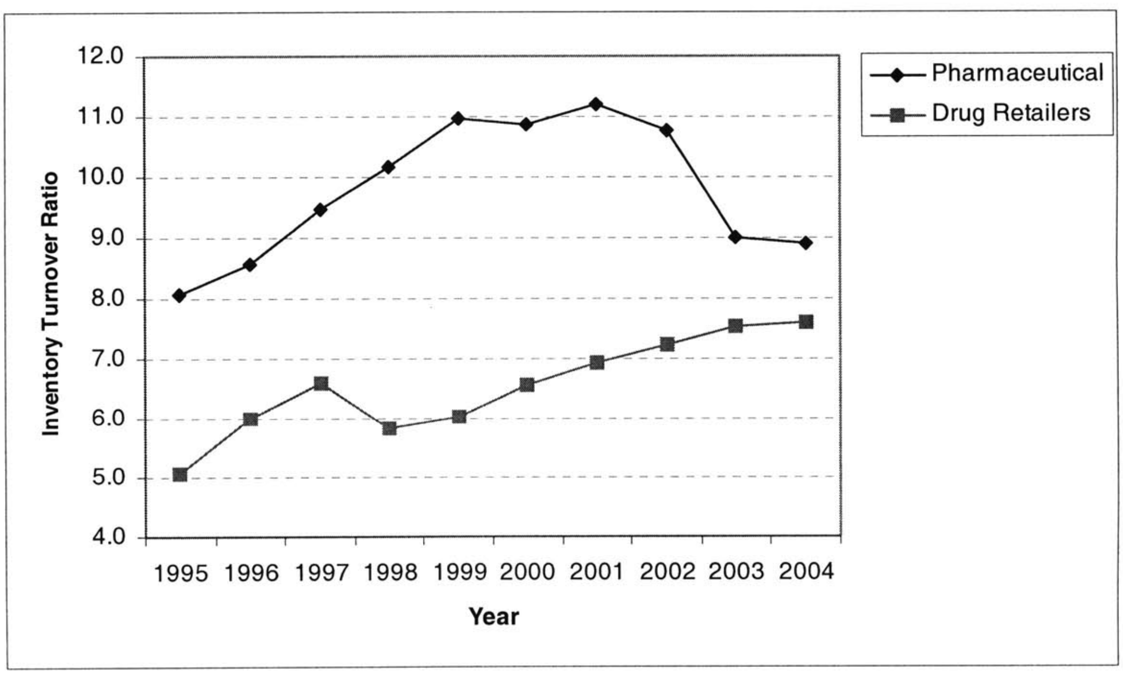
The other two supply chains, the healthcare equipment manufacturers-distributors chain (Figure 4-17) and the pharmaceutical manufacturing-drug retail chain (Figure 4-18), do not show obvious trends in their sub-industries' Inv-T ratios. This may be due to the data issue that the selected sub-industries do not constitute a complete supply chain, i.e., the sample of selected firms is not big enough to represent the sub-industry, or there may be other players (sub-industries) in the supply chain that are not identified. Nonetheless, without opposite trends between the sub-industries' Inv-T ratios, the hypothesis that manufacturers' gains in inventory reduction are at the cost of suppliers' or distributors' losses is still invalid.



Source: calculated by the author based on the S&P CompuStat database (2005)

Figure 4-17.

Inventory-Turnovers in Healthcare Suppliers-Distributors Chain



Source: calculated by the author based on the S&P CompuStat database (2005)

Figure 4-18.

Inventory-Turnovers in Pharmaceutical Manufacturers-Drug Retailers Chain

To investigate the impact of modern logistics and inventory holdings on the demand for industrial space and industrial property markets, I conduct an econometric analysis in Chapter 5. I summarize the findings of the empirical studies of Chapters 4 and 5 in Section 5.4.

CHAPTER 5
EMPIRICAL ANALYSIS II: INDUSTRIAL PROPERTY MARKET AND MODERN INVENTORY CONTROL

As discussed in Chapters 3 and 4, modern logistics not only change the patterns of industrial location choice, causing the dispersion of industrial space, they also change the demand for industrial space in each industrial property market, i.e., given the same level of industrial output, the demand for industrial space may be different. To study the actual impact of modern logistics on the industrial property market, I focus on the aggregate demand for industrial space at the regional market level. I first investigate the impact of industrial mix on the demand for industrial space and then add logistics-based parameters to refine the model. To study the market, I include additional two variables, rent and vacancy rates to build vector-autoregressive models. I derive implications of modern logistics' actual impact by comparing the results with the findings in Chapters 3 and 4.

5.1. Industrial Property Markets

Among the four major commercial real estate markets, the industrial property market has been the least studied one (Rabianski and Black, 1997). Traditionally, researchers study the industrial property market with a similar approach used for the study of office and residential markets. To forecast demand, researchers choose explanatory independent variables, such as manufacturing and distribution employment, gross domestic product (GDP), population changes, inventories, freight flows, industrial output, and industrial investment in manufacturing and retail/wholesales sectors (Wheaton and Torto

1990, Mueller and Lapsosa 1994, Rabianski and Black 1997, AMB 2002). Wheaton (2004) finds that, by 2002, major industrial markets observe different change patterns in warehouse stocks than in earlier years. He attributes the change to the restructuring of global logistic systems, including offshore production, increased international trade (e.g., imports from China to the U.S. west coast), technology substitution, and supply-chain reconfigurations that differ significantly among regions. He argues that the logistic revolution has been changing industrial real estate demand in major industrial property markets since the 1980s.

As discussed in Section 4.1, the industrial dispersion at the national level provides implications concerning modern logistics' impact on industrial location choice. Similarly, at the property-market level, the changes in the demand for industrial space, particularly for the distribution space, provide implications concerning modern logistics' impact on the industrial space market. For example, in a region dominated by a single manufacturing sector, if a large increase in the sector's output is accompanied by a small change in the demand for industrial space, holding other things equal, logistics-based factors should underlie the change. By studying the sector's major logistic systems and SCM strategies, as discussed in Chapter 3, I can derive modern logistics' actual impact on the demand for industrial space and, in turn, on the industrial property market.

In the following model-building section, I start with a dynamic stock-flow model with partial adjustment, derive proper functional forms, and then refine the model by adding logistics-based parameters to improve the model's explanatory power. Finally, I apply the four-quadrant framework, discussed in the following Section 5.2, to develop vector-autoregressive models with panel data.

5.2. Model Building with Logistic Factors

The dynamic stock-flow approach to study commercial property markets is based on the static four-quadrant model. It holds that the property price, P, adjusts quickly to reflect the situation of the real estate demand, D, and the existing stock, S. In a competitive market, S will eventually match D to reach the market equilibrium. The adjustment of physical stocks, however, may be slow and often has lags. To explain the process, Wheaton (1997) develops a dynamic four-quadrant model to study the commercial office market. In the model, he assumes myopic behavior of investors and a steady employment growth rate of δ. The model is specified as:

$E_t = (1+\delta)E_{t-1}$; $D_t = \alpha_1 E_t R_t^{-\beta 1}$; $C_{t-n}/S_t = \alpha_2 P_t^{\beta 2}$; $S_t/S_{t-1} = 1 + C_{t-n}/S_{t-1}$; $P_t = R_{t-n}/i$,

where i denotes the capitalization rate in the office market, E denotes the employment, R is the rent, and α and β are the coefficients to be estimated. In equilibrium: $S_t = D_t$, and the model is solved through computer simulation. Typically, the market definition in a stock-flow model is a metropolitan statistical area (MSA), which is usually considered as a good approximation to a local labor market.

For each MSA with *m* industrial sectors (manufacturing and distribution sectors only), a long-term desired stock of industrial space at time t, S_t^*, depends on the physical space requirement of manufacturing production and distribution inventories. As empirical results have shown (Chapter 4), in the past 15 years, the change of the demand for industrial space is primarily due to the change in the distribution sector. Researchers (AMB 2004, PPR 2003) also find that industrial employment is more powerful than industrial output or regional gross domestic product to explain the industrial space demand. They attribute the finding to (1) the demand for industrial space, particularly for the distribution space, is determined by the physical volume of industrial output and technology used in manufacturing and distribution, (2) output data available are often denominated in value of products rather than in volume so that monetary output is not a proper variable used to forecast physical space demand, and (3) measurement of industrial physical output has been revised in recent years to focus more on improvements in knowledge rather than capital stock, and the change of employment, a variable correlated with productivity, has been identified as a more appropriate independent variable used to forecast industrial space demand (Mueller and Laposa 1994, Wheaton 2004).

In addition, previous studies (Wheaton 1990, Mueller and Laposa 1994, AMB 2004) also show that construction of industrial space generally takes a relatively short time, say, one year, so that the desired stock of industrial space at time t, S_t*, can be represented by the function S* as follows:

$$S_t * = S * (EMP_{1,t-1}, EMP_{2,t-1}, \ldots, EMP_{m,t-1}) \quad (5.1)$$

where $EMP_{j,t-1}$ (j=1, 2, 3, ... m) represents the employment in sector j in year t-1. The actual adjustment of the stock may be spread over several periods, so that I assume a partial stock-adjustment rate δ from time t-1 to t. Because of the short construction time of industrial property, the supply of new space moves closely with the demand, and I thereby assume a one-year lag for the new space buildup. The construction function is:

$$S_t - S_{t-1} = \delta(S_t * - S_{t-1}) \tag{5.2}$$

Assuming a linear relationship among variables and a similar one-year adjustment period in all the industries, I build a simple partial stock-adjustment model:

$$S_t * = \alpha_0 + \sum_{j=1}^{m} \beta_j EMP_{j,t-1} + \varepsilon_t \tag{5.3}$$

Combining Equations (5.2) and (5.3), I obtain the estimation equation for S_t:

$$S_t = \delta\alpha_0 + \delta\sum_{j=1}^{m} \beta_j EMP_{j,t-1} + (1-\delta)S_{t-1} + \delta\varepsilon_t \tag{5.4}$$

To study the elasticity of demand with regard to employment, I transform all the variables into natural logarithms and test the model with the pooled panel data of *n* MSAs. If data permitted, the dummy variable of location could be added to allow the intercept term to vary over the MSA, and the result would be a fixed-effects model:

$$S_{i,t} = \delta\alpha_0 + \delta\sum_{j=1}^{m} \beta_j EMP_{i,j,t-1} + (1-\delta)S_{i,t-1} + \sum_{i-1}^{n} \alpha_i MSA_i + \delta\varepsilon_{i,t} \tag{5.5}$$

where $MSA_i = 1$ for the i-th MSA, ∀ i = 2,3,..., n; and $MSA_i = 0$, otherwise. Due to the data constraint, however, I test the simple model without location dummies.

One important test for the model is the serial-correlation test. If there is a serial correlation among error terms, e.g., a significant first-order correlation:

$\varepsilon_t = \rho\varepsilon_{t-1} + v_t$, where 0<|ρ|<1 and v_t is normally distributed with mean zero, then the covariance between S_{t-1} and ε_t is not equal to zero, and the ordinary least-squares estimators would be biased and inconsistent even if the sample were large. To deal with the serial correlation, I use correction techniques such as the Cochrane-Orcutt procedure, which involve a series of iterations to generate the best estimate of correlation coefficient ρ, to yield parameters with desired properties given the sample is large (Pindyck and Rubinfeld, 1998).

To take into account the logistic impact, I add a logistics-based parameter, the sector-wide inventory turnover ratio calculated in Chapter 4, to refine the model. The updated theoretic function would be

$$S_t* = S*(\theta\ , EMP\ ) \qquad (5.6)$$

where θ is a vector of inventory turnover ratios and EMP is a vector of employment, and the updated estimation model is

$$S_t* = \alpha_0 + \sum_{j=1}^{m} \beta_j (\theta_{j,t-1} EMP_{j,t-1}) + \varepsilon_t \qquad (5.7)$$

where $\theta_{j,t-1}$ represents the inventory turnover ratio of sector j in year t-1. As modern logistics have been a core component in many firms' business models, by adding this parameter, I expect to improve the model's explanatory power.

The dependent variable of the above models is the demand for industrial space; in order to conduct a complete market analysis, I add two key market factors, rent and vacancy rates, to build a simultaneous equation system using the non-structural vector-autoregressive (VAR) technique. As econometricians (Pindyck and Rubinfeld, 1998) have pointed out, economic theories may not be sufficient to determine the right specification, e.g., the theory may be too complicated to allow analysts to derive a precise specification, and there are times when they should let the data specify the dynamic structure of a model. The VAR model is of this type, which makes minimal theoretical requirements on the model's structure. With a VAR model, an analyst only needs to specify the variables and the largest number of lags. The equations in the model are usually constrained to be linear so that an analyst does not need to worry about functional forms.

Based on the dynamic four-quadrant framework, also referring to some theoretical space and financial market analyses (Geltner and Miller 2001, Wheaton 2004, AMB 2004), I propose a VAR model as follows:

$$S_{i,t} = \alpha_{0,1} + \sum_{j=1}^{m} \beta_{j,1} EMP_{i,j,t-1} + \sum_{a=1}^{A} \phi_{a,1} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,1} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,1} V_{i,t-c} + \varepsilon_{i,t,1}$$

$$R_{i,t} = \alpha_{0,2} + \sum_{j=1}^{m} \beta_{j,2} EMP_{i,j,t-1} + \sum_{a=1}^{A} \phi_{a,2} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,2} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,2} V_{i,t-c} + \varepsilon_{i,t,2}$$

$$V_{i,t} = \alpha_{0,3} + \sum_{j=1}^{m} \beta_{j,3} EMP_{i,j,t-1} + \sum_{a=1}^{A} \phi_{a,3} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,3} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,3} V_{i,t-c} + \varepsilon_{i,t,3} \quad (5.8)$$

and the logistics-parameter-refined model becomes

$$S_{i,t} = \alpha_{0,1} + \sum_{j=1}^{m} \beta_{j,1} (\theta_{j,t-1} EMP_{i,j,t-1}) + \sum_{a=1}^{A} \phi_{a,1} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,1} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,1} V_{i,t-c} + \varepsilon_{i,t,1}$$

$$R_{i,t} = \alpha_{0,2} + \sum_{j=1}^{m} \beta_{j,2} (\theta_{j,t-1} EMP_{i,j,t-1}) + \sum_{a=1}^{A} \phi_{a,2} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,2} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,2} V_{i,t-c} + \varepsilon_{i,t,2}$$

$$V_{i,t} = \alpha_{0,3} + \sum_{j=1}^{m} \beta_{j,3} (\theta_{j,t-1} EMP_{i,j,t-1}) + \sum_{a=1}^{A} \phi_{a,3} S_{i,t-a} + \sum_{b=1}^{B} \gamma_{b,3} R_{i,t-b} + \sum_{c=1}^{C} \tau_{c,3} V_{i,t-c} + \varepsilon_{i,t,3} \quad (5.9)$$

where R denotes rent and V denotes vacancy rate; ϕ, γ, and φ are coefficients to be estimated; and all the other variables and parameters denote the same as in Equation (5.7). In this model, I consider stock, rent, and vacancy rates as endogenous variables, and industrial employment as exogenous variables. Because the right-hand sides of all the equations have the same variables and no unlagged endogenous ones, an ordinary-least-squares estimation would generate consistent and efficient estimators (Pindyck and Rubinfeld, 1998). To determine the desired number of lags, I use the Akaike Information Criterion (AIC) and adjusted R^2.

5.3. Result Analysis and Impact Implications

In the simplest multivariate model, I use the current-year stock change (SS1) as the dependent variable and the changes in current-year manufacturing and distribution employment (MESS and DESS) as independent variables. As shown in Table 5-1, consistent with the findings in Section 4-1, the change in manufacturing employment does not have a statistically significant impact on the demand for industrial space, while the change in the distribution sector does. The R-square is very low (0.179), indicating the model's low explanatory power. Then, I apply the partial stock-adjustment model by adding a time-lagged variable, SS0, and the model's explanatory power increases significantly (the R-square rises to 0.715). The coefficient of SS0 is 0.734 and highly significant (Table 5-2), indicating a high first-order autocorrelation of annual stock adjustments. The annual adjustment rate $\delta = 1\text{-}0.734 = 0.266$, i.e., the industrial real estate stock adjusts to the market's desired level at 26.6 percent per annum. Coefficients of both independent variables, however, are not significant. As shown in Appendix 9, replacing the aggregate-employment variables with the variables of disaggregate sector-based employment does not improve the model's explanatory power or make any variables more statistically significant. This shows that the traditional partial stock-adjustment model with the employment variables does not explain the industrial space market well.

Table 5-1.
Model 5-1 Parameter Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4945.376	795.478	6.217	0.000
MESS	0.009	0.039	0.236	0.815
DESS	0.310	0.113	2.745	0.009
R-squared	0.179	F-statistic		4.030
Adjusted R-squared	0.134	Prob(F-statistic)		0.026

Source: calculated by the author using Census and TWR databases (2005)
Notes: Dependent variable SS1=Current-year change of industrial space; C=Intercept; MESS=Current-year change of manufacturing employment; DESS=Current-year change of distribution employment.

Table 5-2.
Model 5-2 Parameter Estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.	VIF
C	503.641	718.987	0.700	0.488	0.000
SS0	0.734	0.089	8.230	0.000	1.130
MESS	0.002	0.023131	0.084	0.934	1.031
DESS	0.118	0.07145	1.653	0.107	1.155
R-squared	0.715	F-statistic		30.112	
Adjusted R-squared	0.691	Prob(F-statistic)		0.000	

Source: calculated by the author using Census and TWR databases (2005)
Notes: Dependent variable SS1=Current-year change of industrial space; C=Intercept; SS0=One-year lagged change of industrial space; MESS=Current-year change of manufacturing employment; DESS=Current-year change of distribution employment; VIF=Variance Inflation Factor, with a value greater than 10 indicating possible multicollinearity.

I also test alternative partial stock-adjustment models with either the manufacturing or distribution real estate stock as the dependent variable, but obtain the same results: only the lagged stock variable is statistically significant while all the others are not. It may be due to the frictions in the space market, e.g., firms may lay off employees during a weak market, but keep the inventory space to prepare for future economic recovery or unexpected demand or simply wait until a lease expires. It may also be due to firms' adopting new inventory strategies and technologies that may reduce the demand for labor but keep the same level of (or even increase) the demand for inventory space. Another possible reason for the failure of the partial stock-adjustment model may be related to the informational inefficiency in the space market. Because private transactions dominate the commercial property market, the new demand may not be reflected timely by the new supply, so that the space market may not respond promptly to the change of manufacturing output or industrial inventories, represented by the employment variables.

In the long term, however, the space market will adjust to its desired stock gradually and the supply will eventually meet the demand. In the four-quadrant framework, it is the level of industrial employment that finally determines the level of the demand for industrial real estate stock. Thus, in the following section, I use the total industrial real estate stock and the total industrial employment as dependent and independent variables, respectively.

As discussed earlier, the industrial real estate market consists of manufacturing, distribution, and research and development (R&D) sectors, with the first two each accounting for more than 45 percent; the change of the demand for industrial space is primarily due to the change in the distribution sector; the demand for the total industrial space and the demand for distribution space follow a similar growing pattern. Thus, in this research, I focus on the demand for total industrial space, although I also study the demand for distribution space to make a comparison.

In the simplest two-variable model, the dependent variable is the total industrial real estate stock, S, and the independent variables consist of manufacturing and distribution employment. The regression results (Table 5-3) show that the distribution employment has a significant effect on the industrial stock: the employment of one more distribution worker, which is assumed to correspond to a given increase in manufacturing production and inventory holdings, would require about 2,700 more square feet of industrial space.

Table 5-3.
Model 5-3 Parameter Estimates

Variable	Coefficient		Std. Error	t-Statistic	Prob.	VIF
C	11947.400		17191.710	0.695	0.491	0.000
ME	0.100		0.157	0.637	0.527	7.843
DE	2.707		0.381	7.111	0.000	7.843
R-squared	0.908	F-statistic			233.061	
Adjusted R-squared	0.905	Prob(F-statistic)			0.000	

Source: calculated by the author using Census and TWR databases (2005)
Notes: Dependent variable=Current-year industrial real estate stocks; C=Intercept;
ME=Current-year manufacturing employment;
DE=Current-year distribution employment;
VIF=Variance Inflation Factor, with a value greater than 10 indicating possible multicollinearity.

I replace the manufacturing employment with the detailed industrial-sector-based data, showing the results in Table 5-4a. Only the variables of the computer/electronics and miscellaneous sectors are not significant. As discussed in Chapter 4, the computer/electronics sector has observed industrial dispersion as a whole, and firms have dispersed their production/distribution facilities to smaller industrial regions/markets. At the same time, as indicated in the study of inventory turn-over ratios, although firms may adopt different business strategies, almost all the firms in the computer/electronics supply chains have improved their inventory control and SCM, thereby reducing the total inventory holdings given the same level of industrial output. The regression results here are consistent with the previous findings: the increased demand for industrial space because of the increased output may be cancelled out by the improvement in inventory control and supply-chain reconfiguration, and, without including inventory-based parameters, the actual impact on the demand is unclear.

As shown in Table 5-4b, by removing the insignificant variables in Model 5-4a, all the variables are highly significant and the R-square is 0.994, showing the model's excellent explanatory power. The one problem with the model is the high variance-inflation factors (VIF) on some variables, which indicate possible multicollinearity. A simple way to check this problem is to investigate the variables' correlation matrix. Given that the correlation between any two variables is less than 0.6, multicollinearity may not be a serious problem.

Table 5-4a.
Model 5-4 Parameter Estimates

Variable	Coefficient		Std. Error	t-Statistic	Prob.	VIF
C	33992.340		9317.103	3.648	0.001	0.000
METALS NONMETALLIC	6.523		0.761	8.569	0.000	64.557
FOOD	6.415		1.250	5.132	0.000	40.813
TRANSPORTATION EQUIP	1.230		0.531	2.318	0.026	20.945
MISC	0.932		0.936	0.996	0.326	38.714
COMPUTER ELECTRONICS	0.234		0.180	1.302	0.201	10.344
APPAREL	-1.194		0.362	-3.301	0.002	24.271
CHEMICALS	-3.031		1.262	-2.402	0.021	70.245
PAPER WOOD	-3.232		0.563	-5.737	0.000	12.236
MACHINERY EQUIP	-5.390		0.961	-5.610	0.000	33.760
DE	1.725		0.178	9.690	0.000	24.729
R-squared	0.995	F-statistic			735.848	
Adjusted R-squared	0.993	Prob(F-statistic)			0.000	

Source: calculated by the author using Census and TWR databases (2005)

Notes: Dependent variable=Current-year industrial real estate stocks; C=Intercept; DE=Current-year distribution employment; EQUIP=Equipment; MISC=Miscellaneous; VIF=Variance Inflation Factor, with a value greater than 10 indicating possible multicollinearity.

Table 5-4b.
Model 5-4 Parameter Estimates without Insignificant Variables

Variable	Coefficient		Std. Error	t-Statistic	Prob.	VIF
C	39095.950		7993.974	4.891	0.000	0.000
METALS NONMETALLIC	6.771		0.735	9.213	0.000	60.085
FOOD	5.799		1.046	5.546	0.000	28.514
TRANSPORTATION EQUIP	1.669		0.429	3.887	0.000	13.708
APPAREL	-1.251		0.297	-4.210	0.000	16.375
CHEMICALS	-3.280		0.792	-4.139	0.000	27.656
PAPER WOOD	-3.393		0.552	-6.145	0.000	11.742
MACHINERY EQUIP	-4.231		0.417	-10.135	0.000	6.364
DE	1.786		0.173	10.338	0.000	23.262
R-squared	0.994	F-statistic			918.390	
Adjusted R-squared	0.993	Prob(F-statistic)			0.000	

Source: calculated by the author using Census and TWR databases (2005)

Notes: Dependent variable=Current-year industrial real estate stocks; C=Intercept; DE=Current-year distribution employment; EQUIP=Equipment; VIF=Variance Inflation Factor, with a value greater than 10 indicating possible multicollinearity.

As Table 5-4b shows, the sectors that observe the increased demand for industrial space with the increased industrial output include food (5.8), metals (6.8), transportation equipment (1.7), and distribution (1.9). All these sectors follow the conventional wisdom that increased output would require more industrial space, which is particularly true in the food and metals sectors. These results are consistent with the findings in Chapter 4. As shown in Table 4-5, among the nine manufacturing sectors, the food (10.4%) and metals sectors (0.0%) have observed the lowest increase or no increase of the sector-wide turnover ratios from 1995 to 2004. The consistent results here further confirm the close relationship between inventory control and the demand for industrial space.

In contrast, apparel (-1.3), paper/wood (-3.4), chemicals (-3.3), and machinery equipment (-4.2) have decreased demand for industrial space as their industrial output increases, implying that firms in these sectors have adopted such efficient an inventory control and SCM that the reduced space demand because of implementation of modern logistics outstrips the increased demand because of the increased industrial output and rising service levels. Modern logistic systems and strategies discussed in Chapter 3 may have been effectively implemented in these sectors, e.g., the quick-response system in the apparel industry and material-requirement planning (MRP) and distribution-resource planning (DRP) systems adopted by the chemicals and machinery equipment industries.

Actually, even in those sectors with positive coefficients, the elasticity of demand for industrial space with regard to industrial employment is less than one (Table 5-5a-b, with dependent and independent variables transformed by natural logarithms). If we assume productivity has not significantly improved, i.e., changes in employment represent changes in industrial output, then one would be the threshold to determine the inelastic or elastic demand for industrial space with regard to industrial output. Given this assumption, all nine manufacturing industries' space demands are inelastic, i.e., the demand for industrial space in these sectors will increase by a relatively small percentage given a certain percentage of output increase. Such results are consistent with the empirical study of industrial inventories in Chapter 4, indicating that the majority of manufacturing industries have improved their inventory control and successfully reduced the demand for industrial space given the same level of industrial output.

Given the same productivity assumption, the elasticity in the distribution sector, which is also less than one, indicates that one percent increase in the distribution output would incur less one percent increase in the demand for industrial space. As discussed in Chapter 4, the aggregate inventory-turnover ratio in the distribution sector had increased by 38 percent in the study period. The results here are consistent with the empirical findings in Chapter 4.

Table 5-5a.
Model 5-5 Parameter Estimates with All Variables Transformed by Logarithms

Variable	Coefficient		Std. Error	t-Statistic	Prob.
C	2.384		0.620	3.847	0.000
METALS NONMETALLIC	0.558		0.080	6.991	0.000
FOOD	0.235		0.048	4.875	0.000
TRANSPORTATION EQUIP	0.126		0.027	4.704	0.000
MISC	0.107		0.059	1.830	0.075
COMPUTER LECTRONICS	-0.032		0.042	-0.751	0.457
APPAREL	-0.089		0.034	-2.601	0.013
CHEMICALS	-0.120		0.057	-2.109	0.041
PAPER WOOD	-0.211		0.033	-6.325	0.000
MACHINERY QUIP	-0.286		0.079	-3.622	0.001
DE	0.625		0.097	6.464	0.000
R-squared	0.991	F-statistic			419.411
Adjusted R-squared	0.988	Prob(F-statistic)			0.000

Source: calculated by the author using Census and TWR databases (2005)
Notes: Dependent variable=Ln(Current-year industrial real estate stocks); C=Intercept; MISC=Miscellaneous; DE=Current-year distribution employment EQUIP=Equipment.

Table 5-5b.
Model 5-5 Parameter Estimates without Insignificant Variables

Variable	Coefficient		Std. Error	t-Statistic	Prob.
C	3.401		0.398	8.544	0.000
METALS NONMETALLIC	0.630		0.049	12.891	0.000
FOOD	0.208		0.045	4.668	0.000
TRANSPORTATION EQUIP	0.154		0.020	7.882	0.000
APPAREL	-0.030		0.015	-1.968	0.056
CHEMICALS	-0.131		0.051	-2.587	0.013
PAPER WOOD	-0.193		0.030	-6.384	0.000
MACHINERY EQUIP	-0.321		0.028	-11.510	0.000
DE	0.509		0.069	7.350	0.000
R-squared	0.990	F-statistic			488.350
Adjusted R-squared	0.988	Prob(F-statistic)			0.000

Source: calculated by the author using Census and TWR databases (2005)
Notes: Dependent variable=Ln(Current-year industrial real estate stocks); C=Intercept; DE=Current-year distribution employment; EQUIP=Equipment.

In order to take into account modern logistics' impact, I refine the model by weighing each independent variable with a logistics-based parameter—the sector-wise inventory turnover ratio (Equation (5.7) in Section 5-2). The results are shown in Table 5-6. Compared to the results in Tables 5-4a and 5-4b, both the F statistic and adjusted R^2 increase, showing the model's increased explanatory power. In addition, all the signs of the estimated coefficients remain the same, but the absolute values increase, i.e., the values shift away from zero, further showing the new model's increased explanatory power. Moreover, the coefficients of computer/electronics and miscellaneous sectors become statistically significant at the 90 percent confidence level, indicating that the new model is theoretically sounder and practically powerful.

Table 5-6.
Parameter Estimates for Model 5-5 with Independent Variables Weighted by Inventory Turnover Ratios

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	31694.37	8029.38	3.95	0.00
METALS NONMETALLIC	8.12	0.84	9.72	0.00
FOOD	7.94	1.18	6.75	0.00
MISC	1.69	0.89	1.91	0.06
TRANSPORTATION EQUIP	1.06	0.40	2.67	0.01
COMPUTER ELECTRONICS	0.29	0.14	2.05	0.05
APPAREL	-2.17	0.55	-3.94	0.00
PAPER WOOD	-3.52	0.59	-6.00	0.00
CHEMICALS	-3.55	1.18	-3.02	0.00
MACHINERY EQUIP	-8.50	1.15	-7.39	0.00
DE	1.98	0.19	10.31	0.00
R-squared	0.996	F-statistic		949.262
Adjusted R-squared	0.995	Prob(F-statistic)		0.000

Source: calculated by the author using Census, S&P, and TWR databases (2005)
Notes: All the independent variables are weighed by its sector's inventory turnover ratio.
Dependent variable=Current-year industrial real estate stocks;
C=Intercept; DE=Current-year distribution employment; EQUIP=Equipment.

As shown in Table 5-6, the food (7.9), metals (8.1), transportation equipment (1.1), and distribution (2.0) sectors still follow the conventional wisdom that increased output would require more industrial space. The apparel (-2.2), paper/wood (-3.5), chemicals (-3.6), and machinery equipment (-8.5) sectors still observe a decreased demand for industrial space as their industrial outputs increase, showing improved efficiency in space management in the U.S. industrial property market. For some sectors, such as the machinery equipment sector, firms have been increasingly moving their component manufacturing offshore with finished goods assembled in the United States. In such a case, it is difficult to tell whether firms have improved their efficiency in industrial-space management, but for the U.S. industrial property market per se, the impact is clear: firms have reduced the demand for industrial space per unit of industrial output.

An interesting result is the changed coefficient of the computer/electronics sector: the coefficient becomes positive and statistically significant, which contradicts the conventional wisdom that the great improvement of logistics and SCM in this sector should have substantially reduced the total demand for industrial space. Such a result is probably because (1) changing manufacturing and distribution technologies may have increased requirements for industrial space given the same level of production and inventories, (2) intensified market competition, short product life cycles, and rising customer service levels may have resulted in product SKU proliferations and increased safety stocks, and (3) the assumption of constant manufacturing productivity used for the model may not be applicable to this sector, as the productivity in computer manufacturing might have dramatically improved in the studied period, so that employment cannot be used as a proxy to industrial physical output. Compared to such more space-efficient sectors as machinery equipment or apparel (i.e., coefficients are smaller), the computer/electronics sector's short product life cycles, SKU proliferations, dramatically improved productivity, and intense market competition may all contribute to its relatively high demand for industrial space.

I also perform a similar regression analysis on the demand for distribution space. As shown in Table 5-7, again, the machinery equipment industry had reduced most significantly in terms of industrial space demand, the apparel and paper/wood industries also reduced their space demand, and these three industries' reductions in the demand for distribution space are even more pronounced than the demand for total industrial space. Such a result indicates that the distributors in their supply chains have improved their inventory management more effectively than their manufacturing counterparts. In the Chemicals industry, the demand for total industrial space had decreased, but the demand for distribution space had increased, implying the more effective implementation of modern logistics by manufacturers than by distributors. The opposite happened in the food industry, whose inventory accounts for about ten percent of the total manufacturing inventory—food distributors seem to have improved their inventory controls, while food manufacturers have significantly increased their demand for industrial space in production.

Table 5-7.
Comparison of Parameter Estimates for Model 5-5 with Different Dependant Variables

	Dependent Variable	
	Demand for industrial space	Demand for distribution space
Sector	Coefficient estimate	Coefficient estimate
Computers/Electronics	0.29	
Apparel	-2.17	-3.49
Chemicals	-3.55	3.66
Miscellaneous	1.69	
Transportation Equipment	1.06	
Paper/Wood	-3.52	-4.29
Machinery Equipment	-8.50	-10.66
Food	7.94	-5.81
Metals/Nonmetallic	8.12	8.08
Manufacturing		
Distribution	*1.98*	*3.04*
Retail		

Source: calculated by the author using Census, S&P CompuStat, and TWR data (2005)
Note: coefficient estimates are not listed for statistically insignificant variables

To build a more comprehensive market model, I include rent (R) and vacancy rate (V) in the VAR models as additional endogenous variables. By testing different time lags, I find that a one-year time lag generates the best-fit statistics, which further justifies the assumption that the supply of industrial space adjusts to the desired demand quickly. As shown in Appendix 10, the total supply in the previous year (lagged supply) significantly influences the supply (positively) and the rent (negatively) in the current year, while the lagged rent does not have a significant impact on any of the three dependent variables (supply, rent, and vacancy rate in the current year), showing that the relationship between supply and demand in the space market is a fundamental factor to determine the performance of the capital market, which is consistent with the basic finance theory of the commercial real estate market.

The results of the VAR model without logistics-based parameters (Appendix 10) are consistent with those of the simple multivariate model (Table 5-4a). The change in the computer/electronics sector still does not have a significant impact on the total space supply, but, interestingly, the change in this sector significantly influences the rent and the vacancy rate. This shows that investors in the capital market may have overestimated the impact of the changes in this sector. By comparison, although the changes in the food, paper/wood, and transportation-equipment sectors have a significant impact on the space supply, they have little impact on rent or vacancy rate, showing that investors and developers may have overlooked the demand impact of such traditional manufacturing sectors as food and paper/wood. Finally, similar to the single equation multivariate models, adding logistics-based parameters improves the model's explanatory power (compare Appendixes 10 and 11) and changes the coefficient of the computer/electronics sector to be statistically significant.

5.4. Summary of Empirical Analysis in Chapters 4 and 5

From the literature review in Chapter 2 and the theoretical analysis in Chapter 3, I cannot reach a conclusion on what should be the actual impact of modern logistics on industrial location choice and the demand for industrial space, but I expect two types of impact: (1) supply-chain reconfiguration restructures industrial manufacturing and distribution networks, locating firms along their supply chains, and (2) modern inventory controls change the demand for industrial space, in particular, the demand for distribution space. I summarize the major findings from the empirical analysis in Chapters 4 and 5 as follows (summary table listed in Appendix 12).

First, aggregately, the changes in the distribution sector have a more significant impact on industrial location choice and property markets than the changes in the manufacturing sector. As modern logistics and SCM become a core component in many firms' business models, the logistic function has been a driving force underlying industrial location choice and the demand for industrial space. Modern manufacturing firms make their location decisions based on the global supply-chain requirements.

Second, as a whole, industries in both the manufacturing and distribution sectors have been dispersed in the past two decades. Firms in these two sectors have been reconfiguring their supply chains by shifting manufacturing and distribution locations from larger industrial regions/markets to smaller ones. The dispersion economies have outstripped the agglomeration economies in firms' industrial location choice, and the economies are especially pronounced in the sectors of computer/electronics, transportation equipment, and miscellaneous that includes office suppliers, toys, etc. Firms disperse their production and distribution to be close to end customers in order to lower the total cost and/or accommodate the increased demand for high service levels. The only exception is the food sector, which has observed a considerable industrial concentration, indicating that the agglomeration economies in this sector still dominate firms' location decisions.

Third, inventory-turnover ratios in the three aggregate sectors, i.e., manufacturing, distribution, and retailing, have been increased, showing that, in aggregate, firms along the entire manufacturing-distribution-retail supply chain have universally adopted efficient inventory control and SCM. The detailed sector-based analysis further confirms that all manufacturing sectors, except the metals/nonmetallic sector, have observed increased inventory turnover ratios, and the increase in the computers/electronics sector is the largest as its inventory turnover ratio almost doubled during the study period.

Fourth, improvement of inventory control is almost ubiquitous in all the industrial sectors, and, within a supply chain, certain players' gains from inventory reductions are not necessarily at the cost of their upstream suppliers' or downstream customers' losses. Modern inventory controls and SCM have enabled the majority of U.S. manufacturing and distribution firms to reduce their inventory holdings given the same level of sales and services.

Fifth, in the manufacturing industry, the demand pattern for industrial space, particularly for distribution space, is generally consistent with the demand pattern for value-based inventory holdings. All the manufacturing sectors except the metals/nonmetallic sector have reduced the demand for industrial space, given the same level of industrial output. But the improvement is not uniform across sectors—the machinery-equipment sector has achieved the highest space efficiency among all the nine manufacturing sectors.

Finally, my empirical analysis shows that the partial stock-adjustment model using yearly data does not explain the industrial property market well.

This may be attributed to the quick adjustment of supply in the industrial space market. My empirical analysis further shows that the model with the employment level other than the employment change as the independent variable has a relatively high explanatory power in forecasting industrial space demand. To take into account the impact of modern logistics, I improve the model by weighting corresponding independent variables with a logistics-based parameter—the sector's inventory turnover ratio in the given year. The results indicate that the new model is theoretically sound and empirically powerful in explaining the industrial real estate market.

CHAPTER 6
CASE STUDIES IN CHINA

As China becomes the global manufacturing center, modern logistics and supply-chain management (SCM) have been playing an increasingly significant role in industrial location choice and regional economic development. Nonetheless, logistics in China are still considerably inefficient: the working capital turnover ratio in China ranges from 1.2 to 2.3, while in the United States, the average is between 15 and 20 (Easton 2005). Ninety percent of an average Chinese manufacturer's time is spent on logistics, while only 10 percent is spent on manufacturing (Economist Intelligence Unit, 2001). Accounts receivable, a key measure of inefficient logistic practice, often exceeds 90 days in many manufacturing firms (Bolton and Wei, 2004). Almost all major cities and regions have invested in some forms of distribution or warehousing centers or logistic parks, but about 60 percent of logistic centers are empty (China Storage Association, 2002).

Given the importance of logistics in modern industrial management, large multinationals and China's domestic manufacturing firms have started investing heavily in modern logistics to optimize their supply chains. The central government has been encouraging firms to implement modern SCM to improve logistic capacity and efficiency. I study the impact of such logistic development on industrial location choice and the demand for industrial space in China, and then compare the findings with those in Chapters 4 and 5 to see the similarity and the difference between China and the United States. Due to data constraints, however, applying the same methodology used in Chapters 4 and 5 to study the China market is not feasible. First, as development of modern logistics in China is still in an early stage, cross-sectional and time-series data on firms' changing inventories are limited. Second, the industrial property market in China is relatively underdeveloped and lack of data makes a systematic empirical analysis infeasible. Also, the capital market, in which listed firms disclose their financial data regularly, has not been well developed, and the information published by some firms is even unreliable. Therefore, I cannot conduct the comprehensive statistical analysis I did for the U.S. market on the China market.

In this chapter, I rely on case studies to find modern logistics' actual or potential impacts on industrial location choice and the demand for industrial space in China. Case studies on representative firms provide direct evidence on actual impacts in a given industrial sector. I conduct case studies in two of China's manufacturing sectors: the traditional steelmaking sector and the relatively modern electric-appliances sector. I start with firms in the steelmaking sector and then turn to an emerging manufacturing firm specialized in home-electric-appliances goods, the Haier Group.

6.1. Case Study of Steelmaking Industry

Steelmaking is an old sector in China, with some of the current plants having been built in the early 1900s. The oldest one, the Wuhan Iron and Steel Plant, was built in 1889 and the second oldest one, the Shanghai Machinery Plant, was established in 1890 (The internet: http://baike.baidu.com/, 2006). As costs of raw materials increase and the demand for quality service demand continues to escalate, profit margins of the traditional steelmaking industry have been shrinking. In order to remain competitive, many steel firms have tried to reduce production lead-time, slash planning-cycle time, and eliminate unnecessary work-in-process inventories. For instance, in the late 1990s, Bethlehem Steel in the United States hired Experio Solution, a consulting firm, to identify areas where the company could retain product and service quality while trimming costs. After the implementation of Experio Solutions' SCM strategy, Bethlehem Steel was able to eliminate overloads, increase output, and identify and refuse orders that it could not fulfill. Consequently, the company reduced its inventory by 15 percent, the production lead-time by one week, and the weekly inventory cost by $1.75 million. (Experio Solutions, 2001)

With the rapidly growing economy, China is becoming a "world factory" and is facing dramatically increased demand for steel products. On the one hand, fast-growing manufacturing sectors, such as automobiles, and traditional steel-consuming sectors, such as construction, all require vast quantities of steel products. On the other hand, upstream raw-material suppliers, such as iron ore and metallurgical coke, are observing either inadequate domestic production capacity or rapidly rising demand in the international market.

A steelmaking supply chain comprises key sectors of raw-material suppliers, steelmaking, and steel-product consumers, including automaker, construction, electric-appliances, machinery equipment, etc. A key raw-material supplier sector is coal and coke. The objective of the coking process is to produce a high-strength coke at minimum cost, which will perform well in a blast furnace. The cost of coke is said to represent a significant proportion, about 15 to 20 percent, of the cost of steel (IEA Coal Research, 2001). China is the largest coke-producing country, with approximately one-third of worldwide production. Also, China exports over half of the global traded coke (IEA, 2001). Thus, China's cokemaking industry is not only a crucial supplier of the domestic steelmaking industry; it also dominates the global coke market.

With a surge in construction and infrastructure investments, demand for steel in China has more than quadrupled since 1980. China consumed more than 130 million tonnes of steel in 2000, becoming the world largest steel consumer. Chinese steelmakers generate three percent of the nation's gross domestic product (GDP), employ more than three million people, and supply 87 percent of the domestic steel market (Woetzel, 2001). It has been a backbone industry of China's economy.

The development of the Chinese steelmaking industry is paralleled by development in its major customer industries, such as construction and manufacturing, with the latter including automobile, electric appliances, and shipbuilding. As shown in Table 6-1, construction and manufacturing are the two largest end customers in the steelmaking supply chain. Regarding the construction sector, since the economic reform in 1979, China has been experiencing an unprecedented urbanization. The tremendous volume of urban construction needs a vast volume of steel products. Also, such manufacturing industries as automobile and electric-appliances all need a vast volume of steel (Hogan, 1999). The automobile industry has been another backbone industry in China's overall economy. The value of the industry's total production was 298.7

billion yuan ($36 billion) in 1998, accounting for 3.8% of the GDP (Friedl Business Information and Partners, 2001). By 2002, China's automobile industry had become the fourth largest in the world, following the United States, Japan, and Germany. Regarding the electric-appliances industry, since the mid 1980s, the industry has observed a dramatic expansion in terms of its total production and global market share. A number of giant appliance manufacturers, like Haier, Changhong, and Kelong, have emerged.

TABLE 6-1
Steel Consumption in China by Market, 1997

Consuming Industries	Steel Consumed (1,000 tonnes)	Steel Consumed (Percent)
Construction	45,110	41.5
Manufacturing	37,950	34.9
Machinery	9,821	9.0
Transportation (Railroads and other)	7,151	6.6
Electrical machinery	3,451	3.2
Mining, quarrying, lumbering	2,660	2.5
Oil and gas	2,445	2.3

Source: Central Iron & Steel Research Institute, Beijing, China. Reference in "China: The Changing Shape of The Chinese Steel Industry." The Internet (http://www.newsteel.com/features/NS9910f3.htm)

As the economy grows rapidly, Chinese steel firms are facing increased demand from downstream customers, tightened supply from upstream material suppliers, and rising costs in transportation delivery. To deal with these problems, steel firms have started cooperating with their suppliers/customers and restructuring their supply chains. Here, I conduct an empirical analysis of the ongoing supply-chain reform in China's steelmaking sector and derive its potential impact on industrial location choice and the demand for industrial space.

As a major steel-production base in China, Liaoning Province's steel sector was dominated by four large state-owned enterprises: Anshan, Benxi, Fushun, and Dalian, which had all experienced serious economic losses in the 1990s. Although many factors underlay their losses, an inefficient logistic system was a major reason. Steelmakers had realized the problem and started reforming their logistic systems since the late 1990s. In the winters of 2003 and 2004, I interviewed managers at major steel firms in Liaoning to study their supply-chain reforms. The following information is mainly from the interviews.

Basically, steel firms in Liaoning have two distribution channels: (i) use direct shipping, i.e., deliver products from steel manufacturers directly to large accounts, and (ii) use intermediate distributors that work as hubs in that they collect intermediate and final products from steel manufacturers and then distribute to various end customers that are usually small accounts. In general, large steel firms rely more on direct shipping, while smaller ones prefer using intermediate distributors.

For instance, Fushun New Steel, a medium-size steelmaker, distributes about 80 percent of its products through intermediate distributors (one-third of this 80 percent is exported to foreign customers), and the remaining 20 percent is shipped directly to large domestic accounts primarily in the construction sector. By comparison, Benxi Steel, a large state-owned enterprise, manages its logistics primarily by direct shipping. The majority of the company's products are shipped directly from the Benxi headquarter manufacturing plants to the large customers in different industrial sectors, including automobiles, electric-appliances, construction, pipelines, and containers. The demand from these large accounts accounted for about 70 percent of its total sales in 2004. The company distributed the remaining 30 percent using intermediate distributors to smaller accounts in the Yangtze River Delta and the Pearl River Delta.

According to my interviews, for large accounts, the direct-shipping mode is more cost effective than the intermediate-distributor mode, because the steel manufacturer has control of the whole supply chain; for small accounts, the intermediate-distributor mode is more cost effective, because these intermediary distributors receive small orders from a large number of customers and their aggregation role enables them to enjoy the scale economies in transportation and inventory management. Also, they are more knowledgeable than large steelmakers in the local market, particularly for small customers. Thus, the two distribution modes have advantages in respective contexts and for different customers.

In terms of transportation, because such base materials as coal, coke, iron ore, and crude steel are generally time-insensitive in delivery, steelmakers often prefer low-cost transportation modes as long as such modes are available. For instance, Fushun New Steel ships its products using trains, trucks, and ocean freight (through the Yingkou port in Southern Liaoning), and on average, ocean freight accounts for more than one-third of the company's total shipments and carries the products not only to overseas customers, but also to domestic ones located near major ports.

For industrial location choice, steelmakers prefer locating their manufacturing plants close to coal and/or iron-ore mines in order to have convenient access to the heavy weight raw materials; or they prefer locating within or close to major industrial zones to have convenient access to major clients. To achieve efficient distribution in a supply chain, those steel manufacturers that rely on direct shipping have established centralized distribution centers (CDCs), usually close to the manufacturer, to manage their supply chains centrally. Such CDCs enable them to enjoy the economies-of-scale in inventory management and reduce inventory safety stocks by pooling risks. By comparison, in the intermediate-distributor mode, distributors usually established regional distribution centers close to the end market in order to respond quickly to the customer's demand. As discussed earlier, large and small steel firms in Liaoning have different preferred distribution modes. Thus, to accommodate their respective needs, large firms prefer owning and operating CDCs by themselves and smaller ones usually outsource the distribution functions to third parties.

Because most raw materials, intermediate components, and final products in the steel sector are durable goods, their distribution is generally time-insensitive. Also, some characteristics of steel production, such as the long lead-time in capacity adjustment and high sunk cost, often place steelmakers at a disadvantageous position in their supply chains when working with their upstream and downstream partners. Price pressure from their powerful upstream raw-materials suppliers and volatile demand patterns of their downstream customers cause steelmakers to hold large inventories. To secure smooth production, major steel firms usually have long-term contracts with both upstream and downstream players in their supply chains. As a result, the requirements for industrial space, including both manufacturing and distribution, have been consistently large.

Since the late 1990s, consolidation has been a major development trend in China's steel industry, which was similar to what their developed-country counterparts had experienced in the mid 20th century (Mueller, 2006). As small steelmakers face volatile prices of such raw materials as iron ore and coking coal, large steelmakers are able to lock in long-term supply contracts at low prices due to their great bargaining power. In my case study, the four major steelmakers in Liaoning that I include in my case study had planned to merge into one company to reduce total costs and increase the negotiation power in international and domestic markets, but, so far, only two have done so. In August 2005, Anshan Steel and Benxi Steel, the two largest steelmakers in Liaoning, which were also among the top ten in China, announced their merger into one giant firm with an annual output of more than 20 million metric tonnes (The Internet: People's Daily, 2005).

There were questions on whether these steel firms were already too large to reap any scale economies from the merger. Compared to their counterparts in developed countries, however, their sizes were still relatively small. For example, as shown in Table 6-2, in 2003, the total output of the four steelmakers in Liaoning (17.19 million tonnes) is less than the output of a large U.S. steel firm, Nucor Steel (17.50 million tonnes). The international experience has shown that consolidation and various forms of alliance help steelmakers reduce production costs, improve research and development (R&D) capacity, enhance negotiation power, and consequently, increase their market shares. Thus, to increase the competitiveness of the industry, the Chinese government has been encouraging consolidation in the steel industry, making new policies to limit the entry of small players (The Internet: www.mmi.gov.cn, 2001).

TABLE 6-2
Steel Output of Selected Firms, 2003

Steel Firm	Steel Output (million tonnes)
Anshan Steel	10.07
Benxi Steel	6.21
Fushun Steel	0.53
Dalian Steel	0.38
Nucor Steel	17.50
United States Steel	14.40

Source: China Steel Yearbook, 2003; United States Steel Co. Annual Report to the United States Securities and Exchange Commission (SEC), 2003; Nucor Co. Annual Report to SEC, 2003).

Consolidation has a profound impact on industrial location choice and the demand for industrial space. First, steel firms in Liaoning are planning to consolidate their logistic functions, e.g., integrating supply chains by implementing advance information technologies, setting up regional distribution centers to pool risks and centralize inventory control. These measures often contribute to the reduction of the total demand for industrial space. As discussed in Chapters 2 and 3, firms with centralized distribution centers have relatively high flexibility in supply-chain design and management; they are able to respond to customers' changing demand rapidly while maintaining relatively low inventory stocks.

Compared to the traditional steelmakers in Liaoning, Shanghai Baoshan Iron & Steel Co. (Bao Steel), China's largest steel firm, has been building sophisticated supply chains strategically. In the early 1990s, Bao Steel strategically designed its supply chains from a global perspective. To secure its raw-material supply, the company established iron ore production bases in Australia and Brazil. Also, by replying on low-cost ocean freight transportation, the company leverages its location advantage in Shanghai, China's largest ocean freight port (China Statistical Yearbook, 2005). In addition, Bao Steel has been integrating its supply chains with its major customers'. It is cooperating with China Changchun No. 1 Automobile Group and directly manages the Group's flat-steel warehouses. The company has built a new steel-manufacturing center in Changchun and a centralized distribution center in Shenyang—a heavy-industry production base in Liaoning Province that is close to Changchun. Bao Steel also integrated supply chains with the Shanghai Automobile Group and the Wuhan Dongfeng Automobile Group, two major automakers in China. In 2003, the company invested in a Japanese automobile manufacturing plant in Guangzhou in order to supply the plant intermediate components (Bao Steel Annual Report, 2004).

In the overseas market, Bao Steel has built a new flat-steel plant in Brazil close to its Brazilian iron ore bases, and is planning to supply its products directly to Brazilian local automakers. In the domestic market, the company has formed an alliance with Wuhan Steel and Capital Steel, another two top steel firms in China, on steel scrap purchasing (The Internet: http://www.erpkm.com/shownews.asp, 2005). As discussed in Chapters 2 and 3, such SCM strategies that not only restructure physical supply chains but also internal coordination mechanisms are fundamental to supply-chain reforms, which are expected to improve efficiency significantly in logistic functions.

Furthermore, similar to many U.S. manufacturing firms as discussed in the previous chapters, Bao Steel has invested heavily in its management information systems (MIS) (Bao Steel Annual Report, 2005). The advanced IT-based inventory control and SCM systems enable the firm to receive, disseminate, and respond to ordering, manufacturing, inventory, and distribution information in a just-in-time manner. Supported by the advanced MIS, the company is able to coordinate with its upstream suppliers and downstream customers effectively and optimize its operations systematically. Compared to its Liaoning competitors, Bao Steel's SCM resembles a modern manufacturing firm in a developed country.

In summary, Bao Steel and the steel firms in Liaoning have been redesigning their supply chains to achieve cost reductions and service-level improvements. As the profit margin is shrinking in the sector, to increase the competitiveness, lowering costs and improving service levels are the two keys for the steel firms to retain or increase their market shares. To secure raw materials and effectively compete in the global market, the steelmakers have been establishing oversea iron-ore bases and steel plants, forming strategic alliances with other steelmakers, implementing advanced IT-based SCM systems, and integrating supply chains with downstream and upstream industries.

At the same time, in order to reap the benefits of modern logistics, sophisticated steelmakers, such as Bao Steel, have been building global SCM platforms to streamline logistic functions and further centralize management and decentralize services. As discussed in the previous chapters, the potential impacts on industrial location choice by implementing such SCM strategies may include consolidated manufacturing plants close to raw material bases and major customers, consolidated intermediate distributors located close to end markets, and centralized distribution centers for intermediate and final products that are located along optimized logistic routes. Potential impacts on the demand for industrial space in the short term may include the reduced demand at both manufacturing and distribution locations compared to the current levels (Li, 2004).

By comparison, most large integrated steel mills in the United States have been consolidated, while small mini-mills target niche markets with their advantages of relatively low overhead costs (Li, 2004). As shown in Chapter 4, the national-level centralization ratio of the metal sector in the United States decreased from 100 to 95 (in H-index, or from 100 to 89 in L-index), indicating that the dispersion of mini-mills might have outstripped the consolidation of integrated steel mills and the resulting trend in the metal sector was dispersion.

The inventory turnover ratio in the U.S. steel industry decreased from 9.9 in 1995 to 5.8 in 2001 and then bounced back to 9.0 in 2004, showing that the efficiency of the industry's inventory control deteriorated in the late 1990s and had since improved, but the turnover ratio was still about 10 percent lower than that in 1995. This contrasts to the aggregate manufacturing industry's changing pattern, which had increased by 20.6 percent in the study period. In Chapter 5, the econometric analysis further shows that the metal sector in the United States is the only sector without significant improvement in the industrial-space management.

As China's steel industry integrates into the global market and competes intensively with global players, as what Bao Steel has been doing, steel firms in China are expected to consolidate and specialize, adopting strategic supply-chain strategies and advanced inventory control. The late-mover advantages may enable them to perform more efficiently than their U.S. counterparts in terms of logistics functions.

A major factor underlying the difference between steelmaking sectors' SCM in the two countries is the different steelmaking processes adopted. In general, steel firms use two processes in steelmaking: basic oxygen furnace (BOF) and electric arc furnace (EAF). About 60 percent of the world iron/steel output comes from the BOF process (Table 6-2), in which pig iron/hot metal is produced from iron ores in a blast furnace and then treated in a BOF to produce crude steel. In the process, coke is an essential ingredient used in blast furnaces. The EAF production process, by contrast, does not involve the use of much coal (except in that the power used may be generated in coal-fired power plants, which is particularly true in China). Using recovered scrap, the EAF production accounts for about 30% of the global steel production, generally of lower grade steel than that produced by the BOF process. Other processes, such as open hearth, for the production of pig iron, do not require coke, but these currently account for only about seven percent of the world production and are economic only under limited circumstances (IEA Coal Research, 2001).

As shown in Table 6-3, the percentage of crude steel produced by EAF in China is only 16 percent, which is much lower than that in the United States (46 percent). A major reason for this situation is the limited supply of steel scrap, a key material in the EAF process, and electricity in China. Compared to the United States, China has limited sources of the steel-scrap supply, which include used motor vehicles and machinery equipment. China's automobile industry is relatively new and per capita car ownership is much lower than that in the United States. Limited supply of steel scrap constrains the development of specialized small or medium-sized steel plants that use the EAF technology, and, as a result, an integrated steel plant is often the only option in China's steelmaking industry.

By comparison, mini-mills have developed rapidly in the United States. It already accounts for about half of the industrial production (Table 6-3). Since the early 1980s, the advent of slab casting for steel that is produced by EAF has resulted in a wave of new investments in the construction of mini-mills in the

United States, and ten new plants were constructed on the base of new technology (Giarrantani and Gruver, 2006).

TABLE 6-3
Cruel Steel Production by Process, 2000

Country	Crude Steel Production (million tonnes)	BOF (%)	EAF (%)	Open Hearth (%)	Other (%)
China	123.7	66	16	2	16
Japan	94.2	70	30	0	0
USA	97.3	54	46	0	0
Worldwide	786.4	60	33	4	3

Source: International Iron and Steel Institute, 2000
BOF = Basic Oxygen Furnace
EAF = Electric Arc Furnace

Compared to mini-mills' flexibility in location choice and firm restructuring, integrated steel plants often have to rely on consolidation to achieve the scale economies in price negotiations and transportation/inventory cost reductions. The difference in implementation of the EAF technology in China and the United States contributes to the different SCM strategies adopted by the two countries' steelmaking sectors, which, in turn, have a significant impact on the sector's industrial location choice and demand for industrial space at each location. Because of the data constrain, however, I propose the study of a specific industry's supply-chain development as a future research direction (Chapter 7).

6.2. Case Study of Haier Group

Compared to the steel sector, the home-electric-appliances sector is relatively new in China, with several appliance manufacturers su   ch as Haier established just in the early 1980s. The main products of this sector are consumer goods, and firms in the sector usually face intensive market competition so that they tend to be active in implementing modern logistics to reduce costs and improve service levels and thereby enhance their competitiveness.

Founded in 1984 in Qingdao on China's east coast, the Haier Group has been the country's leading maker of home-electric appliances and the world's second largest refrigerator maker. The company's sales volume rose from $0.42 million in 1984 to $4.9 billion in 2000, an increase of more than 11,600 times, and it is now a global distributor. The company has established more than 38,000 sales outlets around the world and is selling products in over 160 countries (Haier University, 2001).

Before 1998, same as many Chinese manufacturing firms, Haier managed its supply chains solely as transportation and inventory functions. As customers became increasingly concerned about not only price and quality, but also after-sales services, the company started restructuring its supply chains from 1998, building localized plants, establishing centralized distribution centers, and setting up sales/service outlets in most Chinese cities/towns and major foreign cities. The company's supply-chain restructuring provides a good example to study modern logistics' impact on industrial location choice and space demand in China.

In 1998, the company identified four major problems of its supply-chain system (Li, 2002). First, the distribution network of its manufacturing plants was poorly designed. Lack of centralized distribution centers made it difficult to implement centralized sorting, storing, and distribution; temporary warehouses were dispersed across different regions, incurring unnecessarily high transportation and inventory costs. Second, coordination among the company's internal departments was loosely organized. Different departments used their own MIS, which made it difficult to share ordering, distribution, inventory, and sales information. Third, the company rented many third-party warehouses that were generally used for single type of products and had no computer-based MIS for loading, sorting, inspection, and distribution. Also, their product standardization level was low and, without such modern logistic facilities as standardized shelves and containers, it was time-consuming and costly for the company to inspect, store, deliver, and track the shipment of raw materials, intermediate components, and final products. The situation became worse when their supply chains involved international suppliers and customers. Fourth, the company focused on manufacturing quality control but left providing high-quality services at a low priority, which had impeded its expansion to the global market.

In order to deal with these problems, since 1998, Haier has been implementing its supply-chain reform and making SCM the central component of its business model. The underlying SCM strategy comprised one information flow and three resource networks (Haier University, 2002). One information flow represents the flow of ordering information; three resource networks include (i) a global supplier network, (ii) a global distributor network, and (iii) a computer-based information network. The long-term objective was to achieve three zeros: zero inventory in manufacturing and distribution, zero service distance to customers, and zero working capital (Sun, 2002). As the company's core strategy, SCM has since dramatically changed the company's physical supply chains and organizational structures.

On the one hand, to reap the scale economies of consolidation and the agglomeration economies of information sharing and knowledge spillover, the company built advanced centralized distribution centers (CDC) at strategic locations. They set up the first International CDC in 1999 in the Haier Industrial Park in Qingdao. This 22-meter high, robot-controlled CDC has 18,056 standard shelves with two automatic distribution systems for raw materials and components, respectively. In December 1999, the company built its second CDC in the Huangdao Development District in Qingdao to further increase its centralized distribution capacity. Also, the company built additional two in Germany and Middle East. These CDCs have enabled the company to centrally manage the process flow of ordering, sorting, storing, delivering, and auditing, and effectively reduced inventory costs, e.g., by 2002, the company saved direct warehouse and labor costs by approximately 12 million RMB per year (Li 2002).

On the other hand, locating CDCs close to markets has enabled the company to reduce the lead time of shipping final products to end customers by more than a half (Sun 2001). With computer-controlled distribution systems, the company has lowered inventory costs by having only seven days of safety stocks. In 1999, for the air-conditioning sector alone, Haier saved inventory costs by more than $50 million. In addition, the company has reduced the out-of-stock rate, which had seriously impeded the company's expansion to the global market. Moreover, the SCM reform has forced the company to comply with international standards, reducing the friction in shipping and improving the quality of final products delivered. By 2002, the company had successfully reorganized its distribution network, established large and sophisticated distribution centers at strategic locations, lowered the total requirement for distribution space, improved service levels, and substantially reduced logistic costs.

Two major factors contributed to Haier's successful SCM reform: (i) implementation of advanced information technologies and (ii) proximity to end customers. As many Japanese and U.S. companies did in the 1980s, Haier implemented three just-in-time (JIT) systems: JIT ordering, JIT procurement, and JIT distribution. With the support of sophisticated computer-based supply-chain optimization models and management information systems, the company has streamlined the system flow. First, through the JIT ordering, Haier's suppliers receive orders from the online ordering system, instantly comparing manufacturing requirements to inventories, and replenishing cycle and safety stocks accordingly. Then, through the JIT delivery, after raw materials and intermediate products are shipped to the company's warehouses, the operations departments sort the required components according to the manufacturing plan for next day and deliver them to assembly lines within four hours. Finally, after the manufacturing departments complete production based on the orders received from online business-to-business (B2B) and business-to-customer (B2C) systems, the logistics departments deliver customized products to end customers through the company's global-distribution network.

Such JIT-based operations have greatly improved service levels and reduced the total inventory holdings. As of the summer 2002, Haier sent 100 percent of its orders and paid 20 percent of its bills through the Internet (Sun, 2002). The lead time of ordering decreased from ten days to fewer than three days. The company successfully replaced inventories with shared information and responded to the changing market much faster than before.

At the same time, proximity to customers is another key for the successful SCM reform. The traditional definition of proximity is to be close to existing industrial clusters. In modern logistics, proximity means to be close to the end market to receive the market's signals and meet customers' demand quickly. Since 1998, Haier has built manufacturing plants and distribution centers in many countries, including Germany, Italy, and the United States. Also, the company purchases raw materials and intermediate components directly from local suppliers, such as General Electric in the United States. The company hired local staff to manage its subsidiaries that were encouraged to compete in local markets. Moreover, the company set up customer-service centers in more than 40 major cities and after-sales service outlets in more than 10,000 cities in the world. If outlets in towns and villages are included, the number is more than 60,000 (Li, 2002). Such a localization strategy has enabled the company to lower the costs of duties and taxes, receive and respond to customers' feedback rapidly, and diversify its financial and geographic operation risks. As a result, the company's market share has increased several times within a short time, both domestically and internationally, and the company started building its global brand.

In summary, the implementation of modern SCM has restructured the Haier Group's physical manufacturing and distribution networks, consolidating its distribution centers into strategic locations close to its major markets. Although the demand for industrial space at each location has increased, the total number of distribution centers and the total demand for inventory space have decreased. From 1998 to 2002, the company reduced its warehouse area by 50 percent and total inventory cost from $180 million to about $84 million. During the same period, the company's customer service levels have been improved significantly: the average lead-time of ordering declined from ten days to about three days, the inventory-turnover time declined from 30 days to 13 days, and the number of customized product types increased to more than 10,800 (Li, 2002).

In contrast to the findings in the theoretical analysis in Chapter 3, the results of Haier's SCM reform is clear: it has reduced the total demand for distribution space and consolidated the space to fewer, but larger, distribution centers located along the company's global logistic routes. At the same time, the company has increased manufacturing plants and service outlets to achieve the proximity to end customers. These results are consistent with the findings in the empirical study of Chapters 4 and 5, which show steady increases of turnover ratios, i.e., improved inventory controls, in almost all the manufacturing industries, and an inelastic industrial-space demand with respect to industrial output (elasticity was 0.29).

Regarding the issue of industrial dispersion, in the U.S. computer-electronics sector, of which the home-appliances is a sub-sector, the concentration ratio decreased from 100 to 86 (in the H-index, or from 100 to 82 in the L-index) during the study period, showing the industry's general dispersion trend. For the inventory control and the demand for industrial space, the industry-wide turnover ratio of the home-appliances industry had increased from 6.9 to 7.8. Relatively small firms, such as Applica (from 2.4 to 6.1) and Blount (from 6.4 to 9.3) had achieved relatively large improvement compared to such large firms as Whirlpool (from 9.0 to 8.7—even decreased), Blackdecker (from 5.6 to 6.4), and Maytag (from 11.5 to 9.6—also decreased). Such results might be due to the flexibility of small firms to meet changing demand in the market by implementing advanced inventory technologies. The outcome of Haier's reform is consistent with these findings, implying that the Chinese firm is catching up and, in some areas, even doing better than some large U.S. counterparts.

6.3. Summary of Case Studies

Whereas steel firms in China are concerned about cost reduction and market-power building, modern manufacturing firms, such as the Haier Group, emphasize both cost reduction and service-level improvement. This may be due to their different supply-chain contexts in the domestic and international markets. Haier's supply chains, including its upstream suppliers and downstream customers, operate in an intensely competitive market. Their products are commodities that have to compete on both the supply and demand sides: (i) to reduce costs so as to provide lower-priced products than their competitors and (ii) to improve service levels so as to attract customers and expand markets. Modern logistics and SCM enable such commodity manufacturers to achieve both objectives simultaneously. To reap the full benefits of modern logistics, SCM has been a core component in these firms' business models. As a result, its impacts on industrial location choice and space demand are consistent with the empirical findings from the study on the U.S. market (Chapters 4 and 5).

By comparison, the state-owned steel firms in Liaoning are working with monopolistic upstream raw-material suppliers and powerful downstream customers. They also face fierce competition from peer firms in both domestic and international markets. As a consequence, increasing negotiation power and reducing costs through consolidation or alliance building become their strategic priorities, which, in turn, determine their industrial location choices and space demand patterns. It is noted that, as China's once largest and technically most advanced steelmaker, Bao Steel has been managing its supply chains like a modern manufacturing firm in a developed economy, focusing on strategic supply-chain design and effective information management. But in essence, firms in the traditional steel industry have a different focus in SCM from such modern commodity manufacturers as Haier, and as a result, their location choice and demand for industrial space are subject to more constraints than their modern downstream customers, such as automakers and home-appliances manufacturers.

Nonetheless, for most Chinese manufacturing firms, with the expansion of globalization, advance in information technology, development of efficient markets, and increased demand from sophisticated customers, location choice and demand for industrial space have been and will continue being more or less determined by the requirements of efficient supply chains. Firms have to optimize their supply chains by balancing centralized manufacturing/distribution requirements and decentralized/dispersed service demands. The actual industrial-level impacts are still unclear as a macro-level empirical analysis is not feasible given the limited data, but the case studies in the steel and home-appliances industries have shown that the impacts are generally consistent with the empirical findings in the United States. China's flagship manufacturing firms, such as Bao Steel and the Haier Group, have actively and successfully implemented modern logistics and achieved remarkable results, including large savings in inventory costs, improvement of customer service levels, expanded market shares, secured raw-material supplies, and strong strategic supply-chain alliances.

CHAPTER 7
CONCLUSIONS

With the expansion of globalization and advances in information technologies, supply-chain management (SCM) has been a driving force in industrial restructuring and regional economic growth. In this study, I test the hypothesis that *modern logistics have been restructuring industrial manufacturing and distribution networks, dispersing firms into certain regions to achieve the economies of dispersion, and reducing the demand for industrial space per unit of industrial output*. I define modern logistics as functions and strategies to reduce total costs and improve services levels or increase market shares through inventory reduction and supply-chain network reconfiguration.

The theoretical analysis based on the management-science models cannot provide a clear conclusion on the impacts, while empirical analysis using the U.S. industrial and market data indicate that the location impact of modern logistics have been dominated by the dispersion economies, i.e., aggregately, manufacturing and distribution firms have been dispersed, although different industrial sectors have different magnitudes. At the same time, the improvement of inventory control has been almost universal in the manufacturing, distribution, and retailing sectors, and as a result, the demand for industrial space given the same level of industrial output has been reduced in almost all the sectors. Thus, I have proven my hypothesis, i.e., modern logistics in the United States have dispersed firms across regions and reduced the demand for industrial space given the same level of industrial output.

In this research, I apply a methodology with four steps, starting from a theoretical analysis, followed by statistical and econometric analysis, then case studies, and finally comparative analysis to compare findings from the China case study to the U.S. empirical analysis. Major findings include that (1) as modern logistics play an increasingly important role, distribution functions have been dominating industrial location choice and demand for industrial space; (2) with the expansion of globalization and increased customer demand for high quality services, modern manufacturing firms have been dispersing their production and distribution in order to reap the economies of proximity to customers and end markets; (3) inventory management has been significantly improved with enhanced information technology and transportation capacity, and as a result, the demand for industrial space has been reduced given the same level of industrial output; (4) the improvement is so ubiquitous that, in a supply chain, one player's gains are often not at the expense of its suppliers' or customers' losses; and (5) manufacturing firms in China are catching up as some technically advanced firms have achieved remarkable success in their supply-chain restructuring and inventory management, and the industrial-wide impacts of modern logistics are expected to be similar to the empirical findings from the U.S. study.

With clear evidence from the study in the United States, supplemented by tentative findings from China, my research bridges the gaps between management-science literature on SCM and regional economics literature on industrial location choice and the real estate space market. I provide insights into logistic-based industrial restructuring and regional economic development, which is particularly valuable for industrial and economic development in developing countries, such as China, which are being integrated into global supply chains.

The reason why such a study has not been done before could be attributed to two factors. First, the issue spans several academic fields in economics and management science, and requires an interdisciplinary approach to conduct the research. Second, it is difficult, and sometimes prohibitively costly, to obtain useful and comprehensive industrial and market data, particularly for the data on industrial space markets.

Admittedly, factors other than modern logistics may also contribute to firms' location choice and demand for industrial space. As SCM becomes a core strategy in manufacturing and distribution firms' business models, however, firms' locations choice and demand for industrial space are more or less determined by their supply-chain configuration and inventory requirements, which is particularly true at an aggregate industrial level. One unsolved issue of this research is that, although implementation of modern logistics has proven to have a significant impact on location choice and property markets, the actual process, e.g., when it happens and what are the determining changing points, is still unclear. Empirical analysis can only provide static results, while a detailed firm-based and specific-market focused study would be necessary to analyze the dynamic process of the change, which may provide insight into the fundamental reasons for the change and useful policy implications for sector-based industrial and economic development. This could be an interesting future research direction. Another potential direction is to perform a systematic empirical analysis on the China market and industry using an approach similar to the one I applied to the U.S. market and industry in this research when the data in China become available.

Appendix 1.
Industrial Employment and Industrial Real Estate Stock in Selected 30 Major Industrial Regions (MSAs)
(EMP unit: 1,000 persons; IRE stocks: 1,000 square feet)

MSA Name	Manufacturing EMP	Distribution EMP	IRE Stock
Chicago	462.5	302.7	1,022,947
Los Angeles	490.0	260.7	899,736
Northern New Jersey	282.8	245.8	771,551
Atlanta	169.3	172.4	501,709
Philadelphia	219.8	141.9	483,688
Detroit	315.6	119.7	469,249
Dallas	198.7	157.9	415,251
Houston	186.9	135.7	387,480
Boston	327.0	177.1	364,454
Cleveland	160.7	66.1	326,469
Minneapolis	204.2	101.1	315,486
Riverside	112.9	68.2	283,172
Orange County	181.0	93.6	273,283
Cincinnati	106.4	58.7	263,333
Seattle	146.3	79.5	252,784
Oakland	95.9	60.9	251,247
Fort Worth	96.2	45.3	226,919
Indianapolis	106.6	64.2	225,524
Kansas City	81.4	62.8	222,260
San Jose	172.3	37.8	221,159
St. Louis	143.3	72.8	219,909
Denver	90.0	82.4	218,156
Phoenix	128.8	97.4	215,079
Columbus	71.5	55.1	212,469
Miami	52.3	79.7	191,176
Portland	116.8	68.8	181,311
San Diego	104.8	48.1	176,388
Sacramento	38.8	25.9	175,771
Baltimore	78.0	66.9	172,284
Washington, DC	70.7	85.1	166,753

Sources: United States Census Bureau (2005); Torto Wheaton Research (2005)
Notes: MSA=Metropolitan Statistical Area; EMP=Employment; IRE=Industrial Real Estate

Appendix 2.
Industrial Employment and Industrial Real Estate Stock in 50 Major U.S. Markets, 1980-2002
(EMP unit: 1,000 persons; IRE stocks: 1,000 square feet)

YEAR	Manufacturing EMP	Distribution EMP	IRE Stock
1980	5,580.6	1,857.0	4,998,638
1981	5,515.5	1,889.8	5,156,338
1982	5,068.4	1,835.9	5,309,556
1983	5,200.2	1,893.2	5,406,936
1984	5,398.9	2,020.5	5,535,397
1985	5,303.4	2,066.6	5,720,231
1986	5,216.1	2,100.1	5,880,843
1987	5,281.4	2,171.6	6,037,289
1988	5,320.6	2,265.1	6,185,931
1989	5,282.8	2,285.8	6,338,483
1990	5,134.5	2,273.9	6,463,493
1991	4,896.5	2,215.4	6,532,286
1992	4,753.6	2,210.5	6,574,072
1993	4,698.9	2,232.1	6,613,379
1994	4,761.9	2,300.8	6,659,498
1995	4,819.0	2,367.5	6,747,016
1996	4,911.6	2,429.2	6,855,300
1997	5,039.6	2,514.8	6,994,043
1998	5,011.2	2,584.6	7,146,718
1999	4,912.4	2,626.2	7,308,595
2000	4,908.1	2,669.6	7,450,429
2001	4,492.7	2,628.4	7,610,670
2002	4,194.8	2,571.0	7,704,709
2003	4,008.5	2,540.8	7,769,042

Sources: United States Census Bureau (2005); Torto Wheaton Research (2005)
Notes: EMP=Employment; IRE=Industrial Real Estate

Appendix 3.
Manufacturing and Distribution Employment and Industrial Real Estate Stock in 50 Major U.S. Markets, 1989-2004
(EMP unit: 1,000 persons; IRE stocks: 1,000 square feet)

Year	E_mfg	E_dis	S_mfg	S_dis
1989	5,282.8	2,285.8	2,009,754	3,420,646
1990	5,134.5	2,273.9	2,032,443	3,500,284
1991	4,896.5	2,215.4	2,046,141	3,544,479
1992	4,753.6	2,210.5	2,054,930	3,571,212
1993	4,698.9	2,232.1	2,063,334	3,595,197
1994	4,761.9	2,300.8	2,071,654	3,628,268
1995	4,819.0	2,367.5	2,086,623	3,689,080
1996	4,911.6	2,429.2	2,100,661	3,766,799
1997	5,039.6	2,514.8	2,120,694	3,864,644
1998	5,011.2	2,584.6	2,145,137	3,968,582
1999	4,912.4	2,626.2	2,171,222	4,077,088
2000	4,908.1	2,669.6	2,195,532	4,169,582
2001	4,492.7	2,628.4	2,217,374	4,275,007
2002	4,194.8	2,571.0	2,229,709	4,341,968
2003	4,008.5	2,540.8	2,241,367	4,386,124
2004	4,020.9	2,564.3	2,257,082	4,438,132

Sources: U.S. Census Bureau (2005); Torto Wheaton Research (2005)
Notes: E_mfg=National Manufacturing Employment
E_dis=National Distribution Employment
S_mfg=National Industrial Property Stocks for Manufacturing
S_dis=National Industrial Property Stocks for Distribution

Appendix 4.
Concentration Indices of Industrial Employment and Industrial Real Estate Stock in the United States, 1989-2004

	Manufacturing Employment						Distribution Employment					
YEAR	*L(%)*	*L_index*	*H(%)*	*H_index*	*T*	*T_index*	*L(%)*	*L_index*	*H(%)*	*H_index*	*T*	*T_index*
1989	10.7	100.0	8.5	100.0	0.915	100.0	9.3	100.0	7.9	100.0	0.882	100.0
1990	10.2	95.9	8.3	97.6	0.904	98.9	8.7	93.3	7.6	96.6	0.867	98.4
1991	9.9	92.5	8.2	96.1	0.898	98.2	8.6	92.5	7.6	96.2	0.864	98.0
1992	9.6	90.5	8.0	94.2	0.892	97.5	8.3	89.3	7.5	94.7	0.860	97.6
1993	9.5	89.0	8.0	93.2	0.891	97.4	8.2	87.9	7.3	93.3	0.856	97.1
1994	9.2	86.4	7.9	92.4	0.890	97.3	8.0	85.9	7.3	92.9	0.854	96.9
1995	9.0	84.1	7.8	91.4	0.884	96.7	7.9	84.7	7.3	92.3	0.851	96.5
1996	8.7	81.8	7.6	89.2	0.873	95.4	7.7	82.7	7.2	91.1	0.846	96.0
1997	8.6	80.5	7.5	88.1	0.869	95.0	7.7	82.0	7.2	90.9	0.847	96.0
1998	8.4	79.2	7.5	87.8	0.868	94.9	7.6	81.7	7.1	90.3	0.844	95.7
1999	8.3	77.8	7.5	88.3	0.875	95.7	7.4	79.4	7.1	90.4	0.846	96.0
2000	8.3	77.4	7.5	87.5	0.873	95.5	7.3	78.3	7.1	90.2	0.847	96.1
2001	8.1	76.3	7.4	87.1	0.871	95.3	7.3	78.7	7.2	91.3	0.853	96.8
2002	8.0	75.1	7.5	87.4	0.874	95.5	7.5	80.2	7.2	91.5	0.854	96.9
2003	7.8	73.6	7.4	87.0	0.874	95.6	7.4	79.2	7.2	91.0	0.852	96.6
2004	7.8	73.3	7.4	86.5	0.871	95.2	7.3	78.6	7.1	90.4	0.848	96.1

	Industrial Manufacturing Space						Industrial Distribution Space					
YEAR	*L(%)*	*L_index*	*H(%)*	*H_index*	*T*	*T_index*	*L(%)*	*L_index*	*H(%)*	*H_index*	*T*	*T_index*
1989	18.0	100.0	13.9	100.0	1.139	100.0	7.2	100.0	8.3	100.0	0.954	100.0
1990	17.9	99.3	13.8	99.6	1.136	99.8	7.1	98.1	8.2	99.3	0.952	99.7
1991	17.8	99.0	13.8	99.4	1.137	99.8	7.0	97.2	8.2	99.1	0.951	99.7
1992	17.8	98.8	13.8	99.2	1.136	99.8	7.0	96.7	8.2	98.8	0.950	99.5
1993	17.7	98.5	13.8	99.1	1.137	99.9	7.0	96.4	8.1	98.6	0.949	99.4
1994	17.7	98.4	13.8	99.0	1.137	99.8	6.9	96.3	8.1	98.3	0.948	99.3
1995	17.6	97.7	13.7	98.7	1.135	99.7	6.9	95.7	8.1	97.7	0.946	99.1
1996	17.5	97.2	13.7	98.6	1.136	99.7	6.8	94.7	8.0	97.0	0.943	98.9
1997	17.4	96.7	13.7	98.3	1.134	99.6	6.8	94.5	8.0	96.3	0.940	98.5
1998	17.2	95.6	13.6	97.6	1.131	99.3	6.8	94.0	7.9	95.9	0.938	98.3
1999	17.0	94.4	13.5	97.0	1.128	99.1	6.8	94.0	7.9	95.4	0.936	98.0
2000	16.9	93.6	13.4	96.4	1.126	98.9	6.8	94.3	7.9	95.2	0.935	97.9
2001	16.7	93.0	13.3	95.9	1.124	98.7	6.8	94.8	7.9	95.1	0.935	97.9
2002	16.7	92.6	13.3	95.7	1.123	98.6	6.9	95.4	7.9	95.2	0.935	97.9
2003	16.6	92.2	13.3	95.5	1.121	98.5	6.9	95.5	7.9	95.2	0.934	97.8
2004	16.5	91.5	13.2	94.9	1.119	98.3	6.9	95.4	7.9	95.2	0.934	97.9

Source: calculated by the author based the U.S. Census Bureau (2005) and Torto Wheaton Research (2005) databases.

Notes: H=Herfindhal-Hirschman Index; T=Theil Entropy Coefficient Index; L=Mean Logarithm Deviation Index

Appendix 5.
Markets Ranked by Manufacturing Employment in 2004 and by Percentage Change in Manufacturing Employment from 1989 to 2004

Market Name (ranked by EMP)	EMP_mfg	Change (%)	Market Name (ranked by change)	EMP_mfg	Change (%)
Los Angeles	826	-41	Riverside	79	47
Chicago	630	-26	Sacramento	34	15
Boston	507	-35	Houston	167	11
Northern New Jersey	469	-40	Portland	124	-3
Detroit	354	-13	Atlanta	177	-4
Philadelphia	330	-34	Minneapolis	219	-4
San Jose	249	-31	Phoenix	138	-7
Orange County	236	-23	Oakland	104	-8
Cleveland	233	-31	Dallas	224	-11
Dallas	224	-11	Kansas City	94	-11
Minneapolis	219	-4	Indianapolis	122	-13
Seattle	214	-32	Detroit	354	-13
St. Louis	204	-29	Washington, DC	83	-15
Atlanta	177	-4	Columbus	85	-15
Houston	167	11	San Diego	130	-19
Phoenix	138	-7	Denver	111	-19
Cincinnati	133	-21	Fort Worth	119	-20
San Diego	130	-19	Cincinnati	133	-21
Baltimore	129	-39	Orange County	236	-23
Portland	124	-3	Chicago	630	-26
Indianapolis	122	-13	St. Louis	204	-29
Fort Worth	119	-20	Cleveland	233	-31
Denver	111	-19	San Jose	249	-31
Oakland	104	-8	Seattle	214	-32
Kansas City	94	-11	Philadelphia	330	-34
Miami	89	-43	Boston	507	-35
Columbus	85	-15	Baltimore	129	-39
Washington, DC	83	-15	Northern New Jersey	469	-40
Riverside	79	47	Los Angeles	826	-41
Sacramento	34	15	Miami	89	-43

Source: calculated by the author based on the U.S. Census Bureau (2005) and Torto Wheaton Research (2005) databases
Notes: EMP_mfg=Manufacturing Employment
Change=Percentage Change in Manufacturing Employment

Appendix 6.
Markets Ranked by Distribution Employment in 2004 and by Percentage Change in Distribution Employment from 1989 to 2004

Market Name (ranked by EMP)	EMP_dis	Change (%)	Market Name (ranked by change)	EMP_dis	Change (%)
Chicago	284.7	6.2	Riverside	33.2	107.8
Los Angeles	275.9	-4.1	Phoenix	62	57.7
Northern New Jersey	257.8	-4.8	Fort Worth	30.1	51.5
Boston	178.6	-0.7	Columbus	40.3	40.0
Philadelphia	144.4	-1.7	Orange County	69.5	34.5
Atlanta	137.5	26.6	Dallas	122.5	30.9
Dallas	122.5	30.9	San Diego	37.8	28.6
Houston	118.3	16.6	Indianapolis	50.6	28.1
Detroit	110.2	8.1	Sacramento	20.9	26.8
Minneapolis	85.4	20.4	Atlanta	137.5	26.6
Washington, DC	81.1	7.9	Cincinnati	49.1	23.6
St. Louis	75.8	-7.8	Denver	67.8	22.4
Seattle	74.8	9.4	Miami	67.2	21.6
Baltimore	70.7	-5.9	Minneapolis	85.4	20.4
Orange County	69.5	34.5	Portland	58.2	19.4
Denver	67.8	22.4	Houston	118.3	16.6
Miami	67.2	21.6	Oakland	53.1	13.6
Kansas City	64.9	-0.9	Seattle	74.8	9.4
Cleveland	63.5	1.6	Detroit	110.2	8.1
Phoenix	62.0	57.7	Washington, DC	81.1	7.9
Portland	58.2	19.4	Chicago	284.7	6.2
Oakland	53.1	13.6	Cleveland	63.5	1.6
Indianapolis	50.6	28.1	Boston	178.6	-0.7
Cincinnati	49.1	23.6	Kansas City	64.9	-0.9
San Jose	43.5	-11.7	Philadelphia	144.4	-1.7
Columbus	40.3	40.0	Los Angeles	275.9	-4.1
San Diego	37.8	28.6	Northern New Jersey	257.8	-4.8
Riverside	33.2	107.8	Baltimore	70.7	-5.9
Fort Worth	30.1	51.5	St. Louis	75.8	-7.8
Sacramento	20.9	26.8	San Jose	43.5	-11.7

Source: calculated by the author based on the U.S. Census Bureau (2005) and Torto Wheaton Research (2005) databases

Notes: EMP_dis=Distribution Employment
Change=Percentage Change in Distribution Employment

Appendix 7.
Markets Ranked by Manufacturing Real Estate Stock in 2004 and by Percentage Change in Manufacturing Real Estate Stock from 1989 to 2004

Market Name (ranked by S)	S_mfg	Change (%)	Market Name (ranked by change)	S_mfg	Change (%)
Chicago	458,229	10.7	Riverside	54,543	59.1
Los Angeles	397,314	3.5	San Diego	57,141	41.2
Detroit	207,571	18.4	Phoenix	39,798	34.0
Northern New Jersey	196,495	4.3	Orange County	24,774	32.3
Cleveland	156,731	7.1	Sacramento	20,510	27.2
Philadelphia	141,838	5.2	Washington, DC	17,388	24.5
Boston	117,160	7.9	Atlanta	64,643	20.8
Cincinnati	79,681	12.2	Denver	52,556	20.8
Kansas City	66,222	7.8	Miami	20,470	19.9
Seattle	66,196	16.3	Detroit	207,571	18.4
Atlanta	64,643	20.8	Dallas	29,247	18.0
Indianapolis	60,032	17.9	Indianapolis	60,032	17.9
St. Louis	57,520	6.9	Columbus	36,521	16.5
San Diego	57,141	41.2	Seattle	66,196	16.3
Houston	57,016	15.6	Houston	57,016	15.6
Riverside	54,543	59.1	Minneapolis	51,099	14.9
San Jose	52,662	3.6	Baltimore	21,968	13.4
Denver	52,556	20.8	Oakland	51,607	12.3
Oakland	51,607	12.3	Cincinnati	79,681	12.2
Minneapolis	51,099	14.9	Chicago	458,229	10.7
Phoenix	39,798	34.0	Fort Worth	22,626	9.5
Columbus	36,521	16.5	Portland	23,147	9.4
Dallas	29,247	18.0	Boston	117,160	7.9
Orange County	24,774	32.3	Kansas City	66,222	7.8
Portland	23,147	9.4	Cleveland	156,731	7.1
Fort Worth	22,626	9.5	St. Louis	57,520	6.9
Baltimore	21,968	13.4	Philadelphia	141,838	5.2
Sacramento	20,510	27.2	Northern New Jersey	196,495	4.3
Miami	20,470	19.9	San Jose	52,662	3.6
Washington, DC	17,388	24.5	Los Angeles	397,314	3.5

Source: calculated by the author based on the U.S. Census Bureau (2005) and Torto Wheaton Research (2005) databases
Notes: S_mfg=Industrial Real Estate Stocks in the Manufacturing Sector
Change=Percentage Change in Industrial Real Estate Stock

Appendix 8.
Markets Ranked by Distribution Real Estate Stock in 2004 and by Percentage Change in Distribution Real Estate Stock from 1989 to 2004

Market Name (ranked by S)	S_dis	Change (%)	Market Name (ranked by change)	S_dis	Change (%)
Northern New Jersey	469,691	11.6	Riverside	92,647	114.6
Los Angeles	368,240	22.6	Atlanta	233,304	63.2
Chicago	335,057	37.5	Phoenix	86,517	49.4
Houston	250,808	15.6	Fort Worth	118,864	48.1
Philadelphia	237,017	11.5	San Diego	39,096	46.1
Atlanta	233,304	63.2	Indianapolis	93,044	39.8
Dallas	212,941	35.1	Chicago	335,057	37.5
Orange County	176,606	15.6	Portland	94,226	37.0
Minneapolis	155,107	28.5	Seattle	109,284	36.1
Detroit	134,721	26.6	Baltimore	81,872	35.9
Cincinnati	127,674	32.4	Dallas	212,941	35.1
St. Louis	125,824	17.9	Sacramento	98,665	33.4
Columbus	125,533	31.2	Cincinnati	127,674	32.4
Miami	124,195	19.8	Columbus	125,533	31.2
Fort Worth	118,864	48.1	Minneapolis	155,107	28.5
Oakland	114,546	17.2	Denver	92,961	27.3
Kansas City	111,364	20.1	Detroit	134,721	26.6
Boston	110,471	9.8	Washington, DC	68,775	23.0
Seattle	109,284	36.1	Los Angeles	368,240	22.6
Cleveland	109,011	16.2	Kansas City	111,364	20.1
Sacramento	98,665	33.4	Miami	124,195	19.8
Portland	94,226	37.0	St. Louis	125,824	17.9
Indianapolis	93,044	39.8	Oakland	114,546	17.2
Denver	92,961	27.3	Cleveland	109,011	16.2
Riverside	92,647	114.6	Houston	250,808	15.6
Phoenix	86,517	49.4	Orange County	176,606	15.6
Baltimore	81,872	35.9	Northern New Jersey	469,691	11.6
Washington, DC	68,775	23.0	Philadelphia	237,017	11.5
San Diego	39,096	46.1	Boston	110,471	9.8
San Jose	37,140	5.6	San Jose	37,140	5.6

Source: calculated by the author based on the U.S. Census Bureau (2005) and Torto Wheaton Research (2005) databases

Notes: S_dis=Industrial Real Estate Stocks in the Distribution Sector
Change=Percentage Change in Industrial Real Estate Stocks

Appendix 9.
Parameter Estimates for Partial Stock-Adjustment Model with Sector-Based Variables

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	431.542	803.203	0.537	0.595
SS0	0.745	0.102	7.290	0.000
CHEMICALS	0.511	0.366	1.397	0.174
METALS NONMETALLIC	0.245	0.343	0.715	0.480
TRANSPORTATION EQUIP	0.042	0.177	0.236	0.815
APPAREL	0.029	0.191	0.151	0.881
COMPUTER ELECTRONICS	-0.012	0.069	-0.180	0.858
PAPER WOOD	-0.031	0.338	-0.093	0.926
MISC	-0.200	0.283	-0.706	0.486
FOOD	-0.345	0.500	-0.690	0.496
MACHINERY EQUIP	-0.420	0.422	-0.997	0.327
DESS	0.125	0.089	1.407	0.171
R-squared	0.752	F-statistic		7.729
Adjusted R-squared	0.655	Prob(F-statistic)		0.000

Source: calculated by the author based on the U.S. Census and TWR databases (2005)
Notes: Dependent variable=Current-year change of industrial space; C=Intercept;
EQIP=Equipment; MISC=Miscellaneous;
SS0=One-year lagged change of industrial space;
DESS=Current-year change of distribution space;

Appendix 10.
Parameter Estimates of Vector-Autoregressive Model with Independent Variables of Real Estate Stock, Rent, and Vacancy Rate

	S1	R1	V1
S1(-1)	0.044274	-2.02E-06	2.65E-06
	(0.01849)	(9.5E-07)	(2.8E-06)
	[2.39448]	[-2.13799]	[0.93728]
R1(-1)	217.5558	0.129853	0.430371
	(2253.13)	(0.11541)	(0.34493)
	[0.09656]	[1.12510]	[1.24770]
V1(-1)	574.8276	-0.098427	0.313196
	(1114.12)	(0.05707)	(0.17056)
	[0.51595]	[-1.72468]	[1.83627]
C	24751.77	8.020748	2.238059
	(24367.7)	(1.24822)	(3.73046)
	[1.01576]	[6.42577]	[0.59994]
FOOD	6.006122	6.42E-05	-4.67E-05
	(1.25808)	(6.4E-05)	(0.00019)
	[4.77405]	[0.99586]	[-0.24222]
APPAREL	-1.170999	6.01E-05	-0.000124
	(0.39765)	(2.0E-05)	(6.1E-05)
	[-2.94476]	[2.95166]	[-2.03498]
PAPER WOOD	-3.107495	4.16E-05	-6.11E-05
	(0.58018)	(3.0E-05)	(8.9E-05)
	[-5.35611]	[1.40042]	[-0.68771]
CHEMICALS	-2.792768	0.000300	-0.000511
	(1.33215)	(6.8E-05)	(0.00020)
	[-2.09643]	[4.39744]	[-2.50669]
METALS NONMETALLIC	6.401811	-0.000258	0.000268
	(0.80200)	(4.1E-05)	(0.00012)
	[7.98233]	[-6.27288]	[2.17912]
COMPUTER ELECTRONICS	0.195486	5.31E-05	-8.49E-05
	(0.20464)	(1.0E-05)	(3.1E-05)
	[0.95525]	[5.06351]	[-2.71046]
MACHINERY EQUIP	-4.921210	-9.77E-05	0.000357
	(1.00158)	(5.1E-05)	(0.00015)
	[-4.91346]	[-1.90404]	[2.33122]
TRANSPORTATION EQUIP	1.479263	2.24E-05	-5.55E-06
	(0.54628)	(2.8E-05)	(8.4E-05)
	[2.70789]	[0.80218]	[-0.06640]

MISC	0.566085	6.46E-05	-4.60E-05
	(0.94410)	(4.8E-05)	(0.00014)
	[0.59960]	[1.33604]	[-0.31798]
DE	1.597586	-3.27E-05	4.56E-05
	(0.19205)	(9.8E-06)	(2.9E-05)
	[8.31864]	[-3.32885]	[1.55128]
R-squared	0.995493	0.841162	0.475457
Adj. R-squared	0.993819	0.782166	0.280627
Sum sq. resids	9.28E+09	24.33911	217.3958
S.E. equation	16279.58	0.833908	2.492249
F-statistic	594.6449	14.25776	2.440368
Log likelihood	-536.4701	-52.38446	-106.0305
Akaike AIC	22.46817	2.709570	4.899205
Schwarz SC	23.00869	3.250090	5.439725
Mean dependent	314517.6	7.273265	9.206122
S.D. dependent	207063.7	1.786714	2.938424
Determinant Residual Covariance		9.95E+08	
Log Likelihood (d.f. adjusted)		-716.1728	
Akaike Information Criteria		30.94583	
Schwarz Criteria		32.56739	

Source: calculated by the author based on the U.S. Census and TWR databases (2005)
Notes: Three dependant variables: S=Stock; R=Rent; V=Vacancy Rate;
C=Intercept; EQIP=Equipment; MISC=Miscellaneous;
SS0=One-year lagged change of industrial space;
DESS=Current-year change of distribution space;

Appendix 11.
Parameter Estimates of Vector-Autoregressive Model with Independent Variables Adjusted by Inventory Turnover Ratios

	S1	R1	V1
S1(-1)	0.034342	-2.19E-06	2.54E-06
	-0.01632	-9.40E-07	-3.00E-06
	[2.10461]	[-2.33499]	[0.83842]
R1(-1)	17.92902	0.079148	0.439557
	-2009.54	-0.11563	-0.37268
	[0.00892]	[0.68450]	[1.17945]
V1(-1)	1697.507	-0.121068	0.367635
	-952.134	-0.05479	-0.17658
	[1.78285]	[-2.20986]	[2.08201]
C	14234.32	9.049979	0.995955
	-21760.9	-1.25211	-4.03565
	[0.65412]	[7.22778]	[0.24679]
FOOD_I	7.151873	3.19E-05	5.29E-05
	-1.17654	-6.80E-05	-0.00022
	[6.07872]	[0.47157]	[0.24255]
APPAREL_I	-1.819527	1.19E-04	-2.09E-04
	-0.59842	-3.40E-05	-0.00011
	[-3.04057]	[3.44746]	[-1.88002]
PAPER WOOD_I	-3.684629	6.38E-05	-7.60E-05
	-0.58229	-3.40E-05	-0.00011
	[-6.32777]	[1.90537]	[-0.70349]
CHEMICALS_I	-2.684006	3.28E-04	-0.000454
	-1.24791	-7.20E-05	-0.00023
	[-2.15080]	[4.56242]	[-1.96237]
METALS NONMETALLIC_I	7.827136	-3.25E-04	0.000255
	-0.86933	-5.00E-05	-0.00016
	[9.00368]	[-6.49304]	[1.57993]
COMPUTER ELECTRONICS_I	0.332465	4.91E-05	-6.16E-05
	-0.16558	-9.50E-06	-3.10E-05
	[2.00785]	[5.15362]	[-2.00616]
MACHINERY EQUIP_I	-8.560266	-1.08E-04	0.000371
	-1.22449	-7.00E-05	-0.00023

	[-6.99091]	[-1.53580]	[1.63383]
TRANSPORTATION EQUIP_I	1.145572	3.88E-05	-4.68E-05
	-0.39789	-2.30E-05	-7.40E-05
	[2.87914]	[1.69412]	[-0.63452]
MISC_I	1.273437	3.93E-05	3.19E-05
	-0.88681	-5.10E-05	-0.00016
	[1.43597]	[0.77098]	[0.19395]
DE_I	1.923075	-4.70E-05	5.71E-05
	-0.20543	-1.20E-05	-3.80E-05
	[9.36144]	[-3.97547]	[1.49845]
R-squared	0.997	0.849	0.422
Adj. R-squared	0.995	0.794	0.207
Sum sq. resids	6.97E+09	23.068	239.640
S.E. equation	14109.400	0.812	2.617
F-statistic	792.531	15.191	1.964
Log likelihood	-529.460	-51.071	-108.417
Akaike AIC	22.182	2.656	4.997
Schwarz SC	22.723	3.196	5.537
Mean dependent	314517.6	7.273	9.206
S.D. dependent	207063.7	1.786714	2.938424
Determinant Residual Covariance		7.4E+08	
Log Likelihood (d.f. adjusted)		-7.1E+02	
Akaike Information Criteria		3.1E+01	
Schwarz Criteria		32.26559	

Source: calculated by the author based on the U.S. Census, S&P CompuStat, and TWR databases (2005)

Notes: Three dependant variables: S=Stock; R=Rent; V=Vacancy Rate;
All independent variables are weighed by its sector's inventory turnover ratio;
C=Intercept; EQIP=Equipment; MISC=Miscellaneous;
SS0=One-year lagged change of industrial space;
DESS=Current-year change of distribution space;

Appendix 12.
Summary Table of Empirical Analysis in Chapters 4 and 5

Sector	Consolidation /Dispersion	Inventory-Turnover ratios 1995	2004	Total Change	Annual Change	Demand for industrial space β(θ*EMP)	t-stat	Elasticity	Demand for distribution space β(θ*EMP)	t-stat	Elasticity
Computers/Electronics	Dispersion	8.0	15.4	91.1%	7.5% (2.76)	0.29	2.1				
Apparel	Unclear	5.9	7.6	27.6%	2.7% (1.77)	-2.17	-3.9	-0.03	-3.49	-3.9	-0.1
Chemicals	Unclear	9.5	10.8	13.9%	1.5% (1.73)	-3.55	-3.0	-0.13	3.66	1.9	0.9
Miscellaneous	Dispersion	8.1	9.2	13.9%	1.5% (1.30)	1.69	1.9				
Transportation Equipment	Dispersion	10.6	12.1	13.7%	1.4% (1.24)	1.06	2.7	0.15			
Paper/Wood	Unclear	9.1	10.3	13.3%	1.4% (0.89)	-3.52	-6.0	-0.19	-4.29	-4.5	-0.5
Machinery Equipment	Unclear	7.4	8.3	11.8%	1.3% (0.79)	-8.50	-7.4	-0.32	-10.66	-5.7	-1.3
Food	Consolidation	9.3	10.3	10.4%	1.1% (1.16)	7.94	6.8	0.21	-5.81	-3.0	-0.4
Metals/Nonmetallic	Unclear	8.8	8.8	0.0%	0.0% (0.05)	8.12	9.7	0.63	8.08	5.9	1.1
Manufacturing	*Dispersion*	*8.9*	*10.8*	*20.6%*	*2.1% (2.32)*						
Distribution	*Dispersion*	*7.5*	*10.3*	*37.8%*	*3.6% (2.68)*	*1.98*	*10.3*	*0.51*	*3.04*	*9.7*	*1.5*
Retail		*6.5*	*8.8*	*34.0%*	*3.3% (3.92)*						

Source: calculated by the author based on the U.S. Census data, the S&P CompuStat database and the TWR database (2005)
Notes: numbers in parentheses for Annual Change denote the t-statistics for the null hypothesis of annual change equal zero;
coefficient (β), t-stat, and elasticity are not listed for statistically insignificant variables

BIBLIOGRAPHY

AMB Property Corporation. 2002. *Determinants of Industrial Real Estate Demand*. The Internet: http://www.amb.com/research/

AMB Property Corporation. 2004. *RFID: Rapidly Falling Industrial Demand?* The Internet: http://www.amb.com/research/

Asheim, Bjørn T. 2001. "Learning Regions as Development Coalitions: Partnership as Governance in European Workfare States?" *Concepts and Transformation: International Journal of Action Research and Organizational Renewal*, 6 (1): pp. 73-101.

Altman, Edward. 2000. *Predicting Financial Distress of Companies: Revisiting the Z-Score and ZETA Models*. New York University Stern School of Business: The Internet.

Bao Steel Annual Report, 2004. Shanghai: Shanghai Stock Exchange.

Bao Steel Annual Report, 2005. Shanghai: Shanghai Stock Exchange.

Brealey, Richard A., and Stewart C. Myers, 1996. *Principles of Corporate Finance*. New York: McGraw Hill.

Byrnes, Jonathan L. 2003. "Dell Manages Profitability, Not Inventory." *Harvard Business School Working Knowledge*. The Internet: http://hbswk.hbs.edu/archive/3497.html

Byrnes, Jonathan L. 2003. "The Dilemma of Customer Service." *Harvard Business School Working Knowledge*. The Internet: http://hbswk.hbs.edu/archive/3298.html

Carbonara, N., I. Giannoccaro, and P. Pontrandolfo. 2002. "Supply Chains within Industrial Districts: A Theoretical Framework." *International Journal of Production Economics* 76 (2) (March): pp. 111-218.

Castells, Manuel. 1996. *The Rise of the Network Society*. Malden MA: Blackwell Publishers. pp. 66-67; 92-147.

Chai, Y. W. 1997. "Determinants of NOI for Warehouse Properties," *Real Estate Finance*, 14 (2): pp. 48-54.

The Editorial Board of China Steel Yearbook. 2003. China Steel Yearbook, 2003. Beijing: China Steel Yearbook Editorial Press.

Copacino, William C. and Jonathan L. S. Byrnes. 2001. "How to Become a Supply Chain Master," *Supply Chain Management Review.* (September) The Internet: www.scmr.com.

Coulson, N. Edward and Steven F. Rushen. 1995. "Sources of Fluctuations in Boston Economy," *Journal of Urban Economics,* 38: pp. 74-93.

DiPasquale, Denise and William C. Wheaton. 1996*. Urban Economics and Real Estate Markets.* Englewood Cliffs, NJ: Prentice Hall.

Dunning, John H. 2000. "Regions, Globalization, and the Knowledge Economy: The Issues Stated," *Regions, Globalization, and the Knowledge-Based Economy,*" edited by John H. Dunning. New York: Oxford University Press. pp. 7-41.

Ellram, Lisa M. 1991. "Supply-Chain Management: The Industrial Organization Perspective," *International Journal of Physical Distribution & Logistics Management*, 21 (1): pp. 13-22.

Engle, Robert F. 1979. "The Regional Response to Factor Suppliers: Estimates for the Boston SMSA," *Interregional Movements and Regional Growth*, ed. William C. Wheaton. Washington, DC: The Urban Institute. pp. 157-196.

Esaki, Howard, Marielle Jan de Beur, and Masumi Pearl, 2003. *Transforming Real Estate Finance: A CMBS Primer.* New York: Morgan Stanley Inc.

Fisher, J., David Geltner, and R. B. Webb. 1994. "Value Indices of Commercial Real Estate: A Comparison of Index Construction Methods," *Journal of Real Estate Finance and Economics*, 9 (2): pp. 137-164.

Flaherty, M. Therese. 1996. *Global Operations Management.* New York: McGraw-Hill Companies. pp. 1-41.

Fujita, M. and J. F. Thisse. 1996. "Economics of Agglomeration," *Journal of the Japanese and International Economies,* 10: pp. 339-78.

Geltner, David. 1993. "Estimating Market Values from Appraised Values without Assuming an Efficient Market," *Journal of Real Estate Resear*ch, 8 (3): pp. 325-346.

Geltner, David, and B. Kluger, 1998. "REIT-Based Pure Play Portfolios: The Case of Property Types," *Real Estate Economics*, 26 (4): pp. 581-612.

Geltner, David and Norman G. Miller. 2001. *Commercial Real Estate Analysis and Investments.* Cincinnati, OH: South-Western Publishing.

Gentry, William M., Charles M. Jones, and Christopher J. Mayer. 2003. "*Deviations Between Stock Price and Fundamental Value for Real Estate Investment Trusts*." Columbia University working paper.

Gereffi, G. and E. Korzeniewicz. 1994. *Commodity Chains and Global Capitalism*. Westport, CT: Praeger.

Giarratani, Frank, and Gene Gruver. 2006. "Plant Location and the Advent of Slab Casting by U.S. Steel Minimills: An Observation-Based Analysis," *Economic Geography* 82 (4): pp. 401-419.

Giliberto, S. M., and A. Mengden, 1996. "REITs and Real Estate: Two Markets Reexamined," *Real Estate Finance*. 13 (1): pp. 56-60.

Ginter, James and Bernard J. La Londe. 2004. "Inventory-Turnover—Reaching for the Stars or Spinning Its Wheels?" *ProLogis Research Bulletin, February 2004*, edited by Leonard Sahling. The Internet: http://www.prologis.com/research/

Glasmeier, Amy K. and Jeff Kibler. 1996. "Power Shift: The Rising Control of Distributors and Retailers in the Supply Chain for Manufacturing Goods," *Urban Geography*, 17 (8): pp. 740-757.

Goodman, A. C. and M. Kawai. 1984. "Functional Form and Rental Housing Market Analysis," *Urban Studies*, 21: pp. 367-376

Grenadier, Steven R. 1995. "Local and National Determinants of Vacancies," *Journal of Urban Economics*. 37: pp. 57-71.

Hamilton, F.E.I. 1974. *Spatial Perspectives on Industrial Organization and Decision Making*. London: John Wiley and Sons, Ltd.

Hammond, J. 1990. "Quick Response in the Apparel Industry", *Harvard Business School Case No. 9-690-038*. Harvard Business School: Boston.

Henderson, J. Vernon, Zmarak Shalizi, and Anthony J. Venables. 2001. "Geography and Development," *Journal of Economic Geography*, 1 (1): pp. 81-105.

Hirschman, Albert O. 1958. *The Strategy of Economic Development*. New Haven, CT: Yale University Press. pp. 98-119.

Kennington, J. L. and Helgason, R.V. 1980. *Algorithms for Network Programming*. New York: Wiley-Interscience, John Wiley and Sons.

Kogan, L. and D. Vayanos. 2003. *Finance Theory Lecture Notes*. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, MA.

Kraemer, K. L., J. Gibbs, and J. Dedrick. 2002. *Impacts of Globalization on E-Commerce Adoption and Firm Performance: A Cross-Country Investigation.* Center for Research on Information Technology and Organizations, University of California, Irvine. The Internet: http://www.crito.uci.edu (accessed March 6th, 2004).

Krugman, Paul. 1995. *Development, Geography, and Economic Theory.* Cambridge, MA: The MIT Press. pp. 31-59.

Leung, E. et al. 2002. *Financial Reform and Corporate Governance in China.* Sloan School of Business, Massachusetts Institute of Technology, Cambridge, MA.

Li, Yu. 2002. *Supply-Chain Management and Firm Restructuring*, First-Year Doctoral Research Paper, Massachusetts Institute of Technology, Cambridge, MA.

Li, Yu. 2004. Analytical Input-Output and Supply-Chain Study of China's Coke and Steel Sectors. Master's Thesis, Massachusetts Institute of Technology, Cambridge, MA.

Li, Yu, and Karen R. Polenske. 2004. "Measuring Dispersal Economies," *Entrepreneurship, Spatial Industrial Clusters and Inter-Firm Networks.* London: Springer. pp. 662-692.

Ling, D., and A. Naranjo, 1998. "The Fundamental Determinants of Commercial Real Estate Returns," *Real Estate Finance.* 14 (4): pp. 13-24.

Linneman, Peter. 1997. "Forces Changing the Real Estate Industry Forever," *Wharton Real Estate Review.* Spring: pp. 1-14.

MacCormack, A., L. Newman, III, and D. Rosenfield. 1994. "The New Dynamics of Global Manufacturing Site Location," in *Sloan Management Review.* Summer: pp. 69-80.

Malpezzi, Stephen. 2002. "Hedonic Pricing Models: a Selective and Applied Review," *Housing Economics: Essays in Honor of Duncan Maclennan*, ed. K. Gibb and A. O'Sullivan. The Internet: http://www.bus.wisc.edu/realestate/pdf/

Marshall, A. 1920. *Principles of Economics.* London: MacMillan.

Masters, J. 2002. *MIT Course Reader: 1.260/15.760 Logistic Systems.* Massachusetts Institute of Technology, Cambridge, MA.

McCann, Philip. 1998. *The Economics of Industrial Location: A Logistic-Costs Approach.* London: Springer.

Morgan, Kevin. 1997. "The Learning Region: Institutions, Innovation, and Regional Renewal," *Regional Studies*, 31 (5): pp. 491-503.

Myers, Stewart. 1984. *Finance Theory and Finance Practice.* Interfaces 14: pp. 126-137. Reprinted in Midland Corporate Finance Journal 5, Spring 1987.

Modigliani, F. and M. H. Miller. 1958. "The Cost of Capital, Corporation Finance and the Theory of Investment," *American Economic Review.* 48: pp. 261-297.

Mueller, G.R. and S.P. Laposa. 1994. The Path of Goods Movement, *Real Estate Finance.* 6 (3): pp. 42-50. Fredrick, MD: Aspen Publishers Inc.

Mueller, Hans. 2006. Integrating the Chinese Steel Industry and Trade Policy into 21st Century. The Internet: http://www.aiis.org/index.php?tg=fileman&idx=get&inl=1&id=1&gr=Y&path=Reports&file=AIIS_Report_8_3_06.pdf

National Bureau of Statistical of China. 2005. China Statistical Yearbook, 2005. Beijing: China Statistics Press.

Pereira, Alvaro E. 1997. *Implications for Transportation Planning of Changing Production and Distribution Processes*, PhD Dissertation, Massachusetts Institute of Technology, Cambridge, MA.

Pindyck, Robert S. and Daniel L. Rubinfeld. 1998. *Econometric Models and Economic Forecasts, Fourth Edition.* New York: Irwin McGraw-Hill.

Polenske, Karen R. 2001. "Competitive Advantage of Regional Internal and External Supply Chains," *Regional Science Perspectives in Economic Analysis, Benjamin H. Stevens*, edited by Michael L. Lahr and Ronald E. Miller, Amsterdam, The Netherlands: Elsevier Science, B.V. pp. 259-284.

Polenske, Karen R. 2001. "Taking Advantage of a Region's Competitive Assets: An Asset-Based Regional Economic-Development Strategy," *Entrepreneurship, Firm Growth, and Regional Development in the New Economic Geography.* Trollhätten, Sweden: Uddevalla Symposium 2000, June 15-17. pp. 527-544.

Polenske, Karen R. and Yu Li. 2005. "Measuring Dispersion Economies." *Entrepreneurship and Dynamics in a Knowledge Economy.* London: Routledge. pp. 68-98.

Porter, Michael. 2001. "Regions and the New Economics of Competition," *Global City-Regions*, edited by Allen J. Scott. New York: Oxford University Press. pp. 139-157.

Sharpe, William F., Gordon J. Alexander, and Jeffery V. Bailey. 1995. *Investments*. Englewood Cliffs, NJ: Prentice Hall.

Simchi-Levi, David, Edith Simchi-Levi, Michael Watson. 2001. *Tactical Planning for Reinventing the Supply Chain*. Massachusetts Institute of Technology, Cambridge, MA.

Simchi-Levi, David, P. Karninsky, and E. Simchi-Levi. 2000. *Designing and Managing the Supply Chain*. New York: Irwin McGraw Hill.

Storper, Michael and Richard Walker. 1989. *The Capital Imperative: Territory, Technology, and Industrial Growth*. New York: Basil Blackwell Ltd.

The Internet. 2005. http://www.chinasteel.com/mmi_en/more/moreb.htm

The Internet. 2006. http://www.erpkm.com/shownews.asp

Thibodeau, Thomas G. 2002. *Making Single-Family Property Values to Market Using Hedonic House Price Equations.* Presidential Address to the American Real Estate and Urban Economics Association: Atlanta.

Wheaton, William. 1990. "An Investment Model of the Demand and Supply for Industrial Real Estate," *Journal of the American Real Estate and Urban Economics Association*, 18 (4): pp. 530-547.

Wheaton, William C. 1997. "The Cyclic Behavior of the Greater London Office Market," *Journal of Real Estate Finance and Economics*, 15 (1): pp. 77-92.

Wheaton, William. 2004. *MIT Course Reader: 11.433/15.021 Real Estate Economics*. Massachusetts Institute of Technology, Cambridge, MA.