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River of Traffic: The Spatial Fragmentation of US Ports

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POTTER C. River of traffic: the spatial fragmentation of US ports, *Regional Studies*. Containerization has spatially fragmented the physical functions of US ports by reducing the friction of moving freight through ports to inland destinations. Previous studies of this shift have focused on case studies or selected municipalities. Employing descriptive statistics, regression analysis and geographical information system (GIS) mapping to explore shifts in longshoring, warehousing and trucking employment across the United States, this paper provides two major findings. First, employment in labour-intensive transportation activities, notably warehousing and trucking, is primarily driven by proximity to population concentrations rather than to port infrastructure. Second, a significant proportion of warehousing employment has migrated, forming a band approximately 200–300 kilometres inland.

Port regionalization Spatial fragmentation Containerization Logistics Trucking Warehousing

POTTER C. 河流交通：美国港口的空间碎裂，*区域研究*。货柜化已透过减少从港口将货物运输至内陆目的地的摩擦，在空间上碎化了美国港口的实质功能。过去对此一转变的研究，多半聚焦案例研究或选定的市。本文运用叙述统计、回归分析，以及地理信息系统（GIS）製图，探讨美国海港沿岸、仓储以及货车运输工作的转变，并提出两个主要研究发现。首先，劳力密集的运输活动之工作，特别是仓储与货车运输工作，主要是由至人口集中处的邻近性所驱动，而非至港口设施的邻近性。再者，仓储聘僱工作中，有显着的部分已迁移，形成了大约两百至三百公里长的内地。

港口区域化 空间碎裂化 货柜化 物流 货车运输 仓储

POTTER C. Flux de trafic: la fragmentation spatiale des ports américains, *Regional Studies*. La conteneurisation a entraîné une fragmentation spatiale des fonctions physiques des ports américains par la réduction des frictions nuisant à la fluidité de transport du fret des ports vers ses destinations à l'intérieur des terres. Les études précédentes sur ce changement se sont concentrées sur des études de cas ou une sélection de municipalités. En faisant appel à des données descriptives, à une analyse de régression et à une cartographie établie par un système d'information géographique (SIG) pour examiner les changements intervenus dans les emplois liés au débardage, à l'entreposage et au transport routier sur l'ensemble des Etats-Unis, le présent article permet de faire deux constatations importantes. Premièrement, l'emploi dans les activités de transport à fort coefficient de main d'oeuvre, en particulier dans l'entreposage et le transport routier, a pour moteur principal la proximité avec des concentrations de populations plutôt qu'avec des infrastructures portuaires. Deuxièmement, une part importante des emplois liés à l'entreposage a migré, formant une bande d'environ 200–300 kilomètres à l'intérieur des terres.

Régionalisation des ports Fragmentation spatiale Conteneurisation Logistique Transport routier Entreposage

POTTER C. Verkehrsfluss: die räumliche Fragmentierung von Häfen in den USA, *Regional Studies*. Die Containerisierung hat die physikalischen Funktionen von Häfen in den USA räumlich fragmentiert, da sie die Reibung bei der Beförderung von Fracht an Inlandsziele verringert hat. In früheren Studien über diese Veränderung standen Fallstudien oder ausgewählte Gemeinden im Mittelpunkt. Mit Hilfe von deskriptiven Statistiken, einer Regressionsanalyse und einer Kartierung über das geografische Informationssystem (GIS) zur Untersuchung von Veränderungen des Beschäftigungsniveaus in den Bereichen Güterumschlag, Lagerung und Lkw-Versand in den USA werden in diesem Beitrag zwei Hauptergebnisse ermittelt. Erstens: Das Beschäftigungsniveau in arbeitsintensiven Transportaktivitäten, insbesondere in den Bereichen Lagerung und Lkw-Versand, hängt in erster Linie von der Nähe zu Bevölkerungskonzentrationen und weniger von der Nähe zur Hafeninfrastruktur ab. Zweitens: Im Bereich der Lagerung ist ein signifikanter Anteil der Beschäftigten migriert und bildet ungefähr 200–300 Kilometer landeinwärts ein Band.

Regionalisierung von Häfen Räumliche Fragmentierung Containerisierung Logistik LKW-Versand Lagerung

POTTER C. Flujo de tráfico: la fragmentación espacial de los puertos en EE.UU., *Regional Studies*. La contenedorización ha fragmentado espacialmente las funciones físicas de los puertos estadounidenses al reducir la fricción del traslado de mercancías a través de los puertos a destinos en el interior. En otros estudios previos sobre este cambio, el tema principal fueron estudios de casos o municipios seleccionados. En este artículo utilizamos estadísticas descriptivas, análisis de regresión y mapas del sistema de información geográfica (SIG) para analizar los cambios en el nivel de empleo en las actividades portuarias, el almacenaje y el transporte por camiones en los Estados Unidos, y proporcionamos dos resultados principales. Primero: el empleo en las actividades de transporte con gran cantidad de mano de obra, principalmente en el trabajo de almacenaje y transporte por camiones, depende sobre todo de la proximidad de las concentraciones de población más que de la proximidad de la infraestructura de los puertos. Segundo: un alto porcentaje del empleo en el sector de almacenaje ha emigrado creando una franja de aproximadamente 200–300 kilómetros al interior.

Regionalización de puertos Fragmentación espacial Contenedorización Logística Camiones Almacenaje

JEL classifications: O18, O39, O51, R40

INTRODUCTION

In *The City in History* (1961), LEWIS MUMFORD wrote:

> Wherever the river of traffic slows down, it tends to deposit its load: so it would be usually near the gates that the storehouses would be built, and the inns and taverns congregate, and in the adjoining streets the craftsmen and merchants would set up their shops. […] Thus the gate produced […] the economic quarters of the city. […] The original meaning of 'port' derives from this portal.
>
> (p. 305)

COOLEY (1894) argued that the 'river of traffic' slows down due to the 'mechanical break' caused by the transfer of goods from one mode of transportation to another, producing society's major urban agglomerations. This relationship was particularly visible in the historical port, which teemed with men struggling up and down gangplanks weighted down by bags of coffee, bunches of bananas and crates of goods. Small gantry cranes hoisted painstakingly balanced palettes from ships' holds down to the docks, where they were transferred to handtrucks and ferried off into a labyrinthine set of aisles or warehouses stacked high with goods (BARNES, 1915). This all began to change when an old tanker renamed the *Ideal-X* embarked from a New Jersey pier in 1956 with a number of truck bodies lashed to its deck for delivery to Houston, Texas, inaugurating one of the twentieth century's most profound – if unsung – technological transformations: containerization. After a slow start during which the new technology was developed and standardized, containerization was widely adopted in the 1970s, supplying the indispensable foundation for global trade and production networks (LEVINSON, 2006). At today's most advanced terminals, the longshoremen and checkers who swarmed the docks are now invisible inside buildings behind computerized control panels, while chassis drive themselves down the pier to accept one of the standardized $40 \times 8 \times 8.5$-foot crenellated boxes being hoisted from a ship every two minutes and lowered onto the chassis by cranes over fifty metres high. The containers are then immediately transferred to trucks or trains and hauled directly through the suburbs to inland regional distribution centres, which serve as hubs for collecting and distributing goods. As a consequence, the 'river of traffic' no longer slows down at the port but rather at scattered inland sites.

This technological transformation has spatially fragmented traditional port functions, particularly warehousing and trucking, by enabling firms to relocate inland away from the congestion and high land and labour costs associated with central city ports. This expansion of logistics activities into broader regions, sometimes referred to as 'port regionalization' (NOTTEBOOM and RODRIGUE, 2005, 2009), is of interest to economic development planners concerned with job creation as the relocation of workplaces increases opportunities in some regions while reducing them in others. To provide a comprehensive overview of how containerization has altered the employment landscape, this paper examines both the spatial reorganization of the US logistics network and the impact on employment in the sectors primarily responsible for the physical transport of goods. (Indirect employment has been shown to be independent of transportation nodes elsewhere by, among others, CAMPBELL (1993), GLAESER and KOHLHASE (2003) and POTTER (2010).) This paper applies geographical information system (GIS), summary statistics and spatial regression analysis to employment figures from the US Census Bureau's *County Business Patterns* and container throughput from *Containerisation International Yearbook* from 1974 to 2007 (CONTAINERISATION INTERNATIONAL, 1974–2010). In doing so, it builds upon a growing body of literature by offering higher sectoral, spatial and temporal resolution than previous analyses. The paper proceeds by reviewing the literature on the changing character of relations between ports and cities in the next section. This is followed by a description of the methods applied and sections describing findings for the three sectors examined here: longshoring, warehousing and trucking. The paper concludes with a brief discussion of some implications for logistics-related employment generation strategies.

LITERATURE REVIEW

As the vignette above indicates, the historical port has concentrated the functions of transferring goods from ships to other modes of transport and vice versa, coordinating freight transportation, insuring and financing shipping, storing goods for later movement, and distributing goods to local and regional clients in urban centres and port hinterlands (market areas for imports and exports). However, as has long been recognized, economic and technological change has attenuated the relationship between cities and ports, the 'port–city interface' (HAYUTH, 1982), while simultaneously expanding port hinterlands. In the US case, which is the focus of this study, containerization as a driver of port evolution has been complemented by the development of supply chain management systems (BOWEN, 2008; NOTTEBOOM and RODRIGUE, 2005), low fuel prices and transportation deregulation (CHRISTOPHERSON and BELZER, 2009). The cumulative effect has been one of hinterland market integration and port function spatial fragmentation.

BIRD's (1963) original Anyport model of port evolution was adapted by HOYLE (1989) to describe an idealized spatial evolution of ports. According to this model, cities and ports were closely associated both physically and economically through the end of the eighteenth century, but the rapid commercial and industrial growth generated by the Industrial Revolution induced ports to develop beyond the city confines and stretch away from the city core. Industrial growth, particularly in oil refining, and the introduction of containerization and roll-on, roll-off ('ro-ro') technologies in the mid-twentieth century drove port facilities into separate spaces to accommodate the spatial needs of these new technologies. Between the 1960s and the 1980s further technological change induced the growth of separate maritime industrial development areas. And by the 1990s ports had completely abandoned the original urban core for expansive areas that could accommodate their large-scale operations, leaving the original core open for redevelopment.

Though the general contours of this model have been widely accepted and extended (for example, HALL, 2007; MCCALLA, 2004), it has been critiqued for its sole focus on the land–maritime interface at the expense of examining the inland expansion of logistics networks (NOTTEBOOM and RODRIGUE, 2005, 2009). This critique recognizes that containerization has contributed to the spatial fragmentation of the core port functions both by shifting the land–maritime interface away from city centres (as in Hoyle's model) and by eliminating the costly port-side mechanical break of loading and offloading goods, creating a high-speed 'pass-through' system (CHRISTOPHERSON and BELZER, 2009) that tends toward – but does not achieve – seamless, frictionless movement (THILL and LIM, 2010). As in modular production in other sectors (LANGLOIS, 2002; STURGEON, 2002), the standardization of containers homogenizes space (LEVINSON, 2006) and facilitates the spatial fragmentation of production. In the case of freight transportation, this fragmentation – as will be shown – has manifested itself in the relocation of warehousing (and to some extent trucking) from port areas to more efficient inland areas with lower operating costs. It may thus be more appropriate today to restrict the term 'port–city interface' to the land–maritime interface and speak rather of a 'logistics–urban interface'.

This migration has been documented by both BOWEN (2008) and CIDELL (2010), who find that warehousing is moving to the ex-urban counties of metropolitan agglomerations. BOWEN (2008) confirms SIVITANIDOU's (1996) findings that this relocation prioritizes highway and airport access. CIDELL's (2010) study of fifty US metropolitan areas qualifies this development by identifying growth in core urban counties and by expanding the geographical scale of analysis in a demonstration of the growing concentration of warehousing establishments in the centre of the United States. While these studies provide rare but valuable contemporary empirical assessments (for earlier work, see also MCKINNON, 1983), both focus on intra-urban shifts in warehousing and thus do not look at the United States as a whole. Additionally, CIDELL (2010) aggregates warehousing and trucking establishments, which may be problematic in two ways due to the creation of many single-owner trucking 'firms' through deregulation in the trucking industry (BENSMAN, 2009; CHRISTOPHERSON and BELZER, 2009). First, because Cidell measures sectoral growth using the total number of firms, the analysis may overestimate growth. Second, Cidell assumes that warehousing and trucking co-locate, which is not necessarily the case as trucking firms, especially individual owners, may choose locations intermediate to frequent destinations.

Such fragmentation alters the terrain of employment in the sector, and since CAMPBELL's (1993) study, the connection between ports and employment has been called into question (GROBAR, 2008; HELLING and POISTER, 2000). However, as CHRISTOPHERSON and BELZER (2009, p. 205) point out, 'systematic analysis of investments and employment in places – within and across metropolitan areas – is rare'. Instead, analysis of this spatial fragmentation has taken two basic forms. One set of studies looks across sectors but remains generalized or evaluates individual case studies (for example, HESSE, 2006; NOTTEBOOM and RODRIGUE, 2005; RODRIGUE and NOTTEBOOM, 2006). The other set of studies, like those in the preceding paragraph, examines individual sectors within the logistics network. JACOBS *et al.* (2011), for instance, find that advanced maritime producer services (AMPS), which include insurance, financing and other producer services, are more likely to locate near customers or similar firms serving other sectors than to transport flows. This

study attempts to build on these studies by providing a systematic analysis of the location of employment in major freight-related activities.

METHODS

This paper employs descriptive statistics, GIS mapping and regression analysis to evaluate the US transportation system's geographical shift. Container movement data for this study are drawn from CONTAINERISATION INTERNATIONAL (1974–2010). Employment data were obtained from *County Business Patterns*, which is prepared annually by the US Census Bureau and contains county-level information on total annual pay and total employment by firm size at detailed sectoral level, making it appropriate for such a study and consistent with studies by BOWEN (2008) and CIDELL (2010). Post-GIS was used to link these data to historical, county-level geographical files generated by the National Historical Geographic Information System (NHGIS) (MINNESOTA POPULATION CENTER, 2004) to generate maps and calculate distances from county centroids to transportation nodes.

Close attention is paid to the sectors of general warehousing and storage, general freight trucking, and marine cargo handling (longshoring). Railroad employment is not included in the *County Business Patterns* datasets and has therefore been excluded from this study. Note that the move in 1997 from the Standard Industrial Classification (SIC) to the North American Industrial Classification System (NAICS) has a minor effect on employment figures for two categories. SIC classifications for marine cargo handling included port and harbour operations, which accounted for 17% of sales or receipts. Also, general warehousing and storage originally included the separate NAICS category of lessors or mini-warehouses and self-storage units (533130), which has been retained to increase comparability. Industrial classification codes employed in this analysis are listed in Table 1.

The paper employs a series of cross-sectional regressions for the years 1974, 1984, 1994 and 2007, which avoids periods of recession. The dependent variable in all regressions is the log of an estimate of total employment in the given sector. Because *County Business Patterns* suppresses employment data for identifiable firms, total employment was calculated according to a Poisson regression of total employment against the number of firms by firm size in counties without suppressed data across all sectors for each period. Independent variables include geographical variables as well as other socioeconomic indicators typically used to predict industrial location. A number of variables are drawn from the US Decennial Census administered immediately prior to the period evaluated. Since potential clients and workers are easier to find in high population areas, the log of county population density (*POPDENLOG*) has been included. The log of per capita income for each county (*INCPCLOG*) has been included since lower incomes imply lower wages and, to the contrary, higher wages may indicate higher consumption. These regressions employ the percentage of the adult population with high-school educations (*HS*) and the percentage with at least a bachelor's degree (*BA*) as measures of a county's relative skill level. Finally, since firms may seek minority and foreign populations, the percentage of non-white county residents (*NONWHITE*) and the percentage of foreign-born residents (*FOREIGN*) are included. In addition to census data, non-industry-specific state-level corporate tax rates for large businesses (*TAXRATE*) were collected from the Council of State Governments' *The Book of the States* for 1978, 1984, 1994 and 2004, as firms may choose their location on the basis of tax rates.

Three variables of primary interest are added to this basic regression model: *PORT*, *AIRPORT* and *INTERMODAL*. These measure the distances (as multiples of 100 km) from each county to the nearest port, airport and intermodal terminal. County location was determined by calculating the county centroid. Port locations for all major North American ports listed in CONTAINERISATION INTERNATIONAL (1974–2010) were determined by the latitude and longitude provided by the United Nations location code system (UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UNECE), 2007) and augmented with information from WORLD PORT SOURCE (2009). Though this excludes some small ports that handle containers, none of those excluded has foreign calls. Airport locations were determined by selecting those airports with customs landing approval from the Federal Aviation Administration (FAA) as of 2002 (FEDERAL HIGHWAY ADMINISTRATION (FHWA), 2007). This excludes many local airports, but ensures that all airports approved

Table 1. Industrial Classification Codes for port-related industries under Standard Industrial Classification (SIC) and North American Industrial Classification System (NAICS) codes and bridges indicated

Industry	1974–1984	1989–1994	1999	2004–2007
General freight trucking	4210	4210	484100, 484200	484100, 484200
Marine cargo handling	4463[a]	4491[a]	488320	488320
General warehousing and storage	4225	4225	493110, 531130	493110, 531130

Note: [a]Only 83% of employment in these categories are marine cargo handling.
Sources: US Census bridge websites and original *County Business Patterns* (CBPs) documentation.

Table 2. Variables collected for analysis

Variables	Descriptions
EMPLOG	log of total employment in the selected industry classification
POPDENLOG	log of the population density
INCPCLOG	log of per capita income
TAXRATE	Tax rate from the previous period (%)
BA	Percentage of the population with a bachelor's degrees or higher
HS	Percentage of the population with a high-school diploma
NONWHITE	Percentage of the population that is non-white
FOREIGN	Percentage of the population that is foreign born
PORT	Kilometers from the county centroid to the closest port (hundreds)
AIRPORT	Kilometers from the county centroid to the closest airport with customs landing approval (hundreds)
INTERMODAL	Kilometers from the county centroid to the closest rail-based intermodal terminal (hundreds)

Sources: US Census Bureau, Council of State Governments, Federal Highway Administration (FHWA), National Historical Geographic Information System (NHGIS), and calculations made by the author.

Table 3. US employment by industry as total (thousands) and percentage of the US total

		1974	1984	1994	2007
Longshoring	Total	82	73	52	67
	%	0.13	0.09	0.06	0.06
Warehousing	Total	43	26	78	527
	%	0.07	0.03	0.08	0.44
Trucking	Total	1002	1139	1552	1458
	%	1.58	1.47	1.6	1.21

Source: County Business Patterns (CBPs).

to serve as ports of entry for freight are included. Finally, the location of intermodal terminals, which serve as points for transferring freight between rail and either ships or trucks, was based on data provided by the FHWA (2007) for 2002. These terminals are located both on the coast and inland and capture the relative importance of rail. One caveat must be added, however. As far as the author has been able to determine, the only complete maps for these infrastructure nodes date from 2002. Therefore, all these nodes are treated as if they existed throughout the time period studied. This is highly unlikely, but it may well be the case that most of these facilities existed in one form or the other throughout the period. For these three variables, positive values indicate that employment in the particular sector increases as the distance from the county to the port, airport or intermodal terminal increases.

Though spatial autoregression is not specifically accounted for in these analyses, residual plots are well behaved and the standard errors are small. Together, these indicate that clustering effects are accounted for through the distance variables. Additionally, the introduction of quadratic terms for the distance variables proved insignificant and to have no impact on the other variables.

FINDINGS

Overall, containerization has coincided with a large numeric increase in logistics-related employment, especially after 1995, though the three sectors examined here now account for a slightly lower proportion of US employment (under 2%) than in 1974. As Table 3 shows, warehousing has increased at a much higher rate than US employment as a whole, accounting for a significantly higher proportion of total US employment over the three decades studied. Meanwhile, freight trucking has marked a solid advance in employment numbers, but the sector's growth has been slower than that of the United States as a whole. The most highly publicized change has been the precipitous and uneven decline in longshore work, though employment is enjoying a contemporary resurgence on the West Coast. The following sectors examine each aspect of the transportation network more closely.

Ports

The physical requirements for ports limit the number of suitable locations and have thus resulted in a relative constancy in port location. Ports require deep channels and berths to allow ships to access and anchor alongside docks that span their entire length. These docks are preferably in sheltered harbours with ample dockside storage space and ready access inland, as discussed above (FRANKEL, 1987). Today, suitable port sites are generally not located upriver, because this adds time and cost to shipping. These demands have always limited the number of available sites and encouraged the active development of an even smaller number.

With today's massive ships, the requirements for dock length and channel and berth depth have increased enormously, resulting in the reduction of some ports' importance, including some formerly major ports like Philadelphia and Boston. It has also led to the active expansion of more accessible ports through the construction or redesign of terminals, like New York, Hampton Roads and Los Angeles/Long Beach. But it has not led to the construction of entirely new ports in the United States. Thus, in the process of spatial fragmentation the land–maritime cargo transfer function of ports has remained anchored, though the relative importance of individual port complexes has shifted.

The dominance of container shipping activity by a select number of ports has also been influenced by the nature of global trade. In 1976, the East Coast port range, which includes Canadian ports in the Maritime Provinces, processed 50% more cargo than the West Coast port range, which includes Canadian ports in British Columbia and Pacific Coast ports in Mexico, and nine times as much cargo as the Gulf Coast port range (3.3 million versus 2.2 million and 0.4 million TEUs, respectively). (A twenty-foot equivalent (TEU) is the basic unit of measurement for container volume, usually representing a $20 \times 8 \times 8.5$-foot space.) However, while container traffic has skyrocketed in all three port ranges, the growth of trade between Asia and North America has shifted the centre of gravity from the populous East Coast to ports along the Pacific Rim (DICKEN, 2003). This trend has been exacerbated as ships have outgrown the Panama Canal. Thus, the largest transpacific trade ships are currently unable to pass through the canal and reach the East Coast, resulting in more cargo being discharged on the West Coast. This change led the West Coast to outstrip the East Coast by the mid-1980s and now exceed it by over 60% (26.6 million versus 16.4 million TEUs).

Each port range exhibits the presence of a dominant port complex. On the East Coast, it is the Port of New York and New Jersey (MCCALLA, 1999). On the West Coast, it is the adjacent ports of Long Beach and Los Angeles (FOWLER, 2006). And on the Gulf Coast it is Houston. In 1976 the Port of New York and the adjacent ports of Long Beach and Los Angeles handled well over 1 million TEUs each, while Houston lagged far behind with roughly 200 000 TEUs. By 2007, Long Beach and Los Angeles each handled roughly 8 million TEUs, while the Port of New York and New Jersey handled just over 5 million TEUs, and Houston moved approximately 1.6 million TEUs (CONTAINERISATION INTERNATIONAL, 2006).

It is also worth noting that these four ports far outstrip their nearest competitors. New York and New Jersey handle more than twice the volume of Charleston and Norfolk; Los Angeles and Long Beach handle more than four times that of Oakland, Tacoma, Seattle and Vancouver; and Houston handles roughly eight times the traffic in New Orleans and Gulfport. These ports are all located in the highest and densest population centres within each port range, lending weight to the claim that global liner companies choose to direct their traffic as close to their customer base as possible.

There are at least two countervailing tendencies to the shift toward the West Coast, however. First, the Panama Canal expansion will permit the passage of today's largest ships by 2014 (PANAMA CANAL AUTHORITY, 2009), facilitating East Coast access from Asia. The second is shippers' response to the ten-day 2002 West Coast port lockout. In the wake of failed labour negotiations between the International Longshoremen's and Warehousemen's Union (ILWU) and the employers' organization, the Pacific Maritime Association (PMA), the shipping organization locked the union out for ten days before President George W. Bush intervened, invoking the Taft–Hartley Act to force employers to reopen the docks and workers to return. The impact of this crippling event has induced a number of large producers, distributors and retailers to increase the flexibility and redundancy of their supply chains by developing routes to both coasts, in particular by expanding East Coast routes (HALL, 2004).

These shifts are also reflected in longshore employment. As a capital-intensive technology, containerization had cut total US longshore employment (SIC 4463 and NAICS 488310 and 488320) by more than 35% between 1974 and 1994. This impact was felt primarily on the East Coast. Employment on the West Coast remained fairly constant until the early 1990s, after which California gained over 10 000 longshore jobs. Though this substantial increase parallels the rapid growth in container throughput in California, especially in Los Angeles and Long Beach, the ratio of longshore workers to total TEU throughput has dropped from 8.17 to 1.30 workers per 1000 TEUs on the West Coast over the period examined here. This implies an ongoing increase in efficiency that reduces the potential employment generated by increasing throughput. This trend is likely to continue as today's most advanced terminals are fully automated and require few longshore workers.

Warehousing

The most significant spatial change in the logistics infrastructure is the location of warehousing. Since the advent of containerization, warehousing has increased as an activity, become geographically more evenly distributed, and developed new concentrations a few hundred kilometers in from the coast and across the middle of the country. By facilitating rapid, comparatively low-cost inland freight movement, containerization has altered warehouse siting considerations, amplifying the tension between proximity to customers

and scale and operating costs. On the one hand, to reduce overall shipping costs and facilitate increasingly demanded local customization, firms have sought to locate the final stages of production, including packaging (in boxes or displays) and sometimes assembly, to locations closer to their customer base. On the other hand, firms have come to rely more heavily on large-scale warehousing, especially distribution centres, to manage complex regional or national supply chains (BOWEN, 2008). Thus, warehousing location is simultaneously pulled toward their customer base in large agglomerations and toward more central locations to serve large geographical networks. It should be noted that this tension exists at multiple geographic scales due both to the size of a firm's market area and to its supply chain management strategy. To illustrate warehousing's spatial shift, a series of maps and regression data follows. The maps are of two types. The first four maps (Figs 1–4) show total employment in warehousing for each county. The last map (Fig. 5) employs warehousing's location quotient to illustrate the county-level concentration of warehousing employment in 2007. (The location quotient represents the ratio of local sector employment to total local employment divided by the ratio of national sector employment to total national employment. Thus, a value greater than 1.0 represents a greater than average concentration of sector employment in the locality and a value less than 1.0 represents a less than average concentration.)

Overall increase in warehousing employment. The maps of total employment illustrate the massive overall increase in warehousing employment. Simply, since darker colours represent higher numbers of warehousing workers, the progressive darkening of the maps reflects this increase. Table 3 shows these figures more precisely. Warehousing employment has increased substantially, tripling from roughly 30 000 in 1970 to almost 100 000 in 1999 and then increasing by well over 400% to over 500 000 in the last decade. Unlike other aspects of freight-handling work, warehousing has also increased as a proportion of total employment, particularly over the last decade. In summary, these maps and Table 3 show that warehousing employment has increased both in absolute and relative terms.

Growth in the absolute number of warehousing jobs has been particularly high in the immediate vicinity of ports, as is evident in the total employment series of maps (Figs 1–4). For example, Los Angeles County shows the highest number of jobs (over 1000) in 1974, with the surrounding counties having fewer than 500. By 2007, LA County has roughly 18 000 warehousing jobs and the surrounding counties have over 1000. Elizabeth and Newark, New Jersey, meanwhile, have fewer than 500 in 1974 and over 5000 in 2007. However, the relative importance of warehousing employment as a percentage of total employment in the economies of these counties has remained steady and even low relative to the national average (Fig. 5).

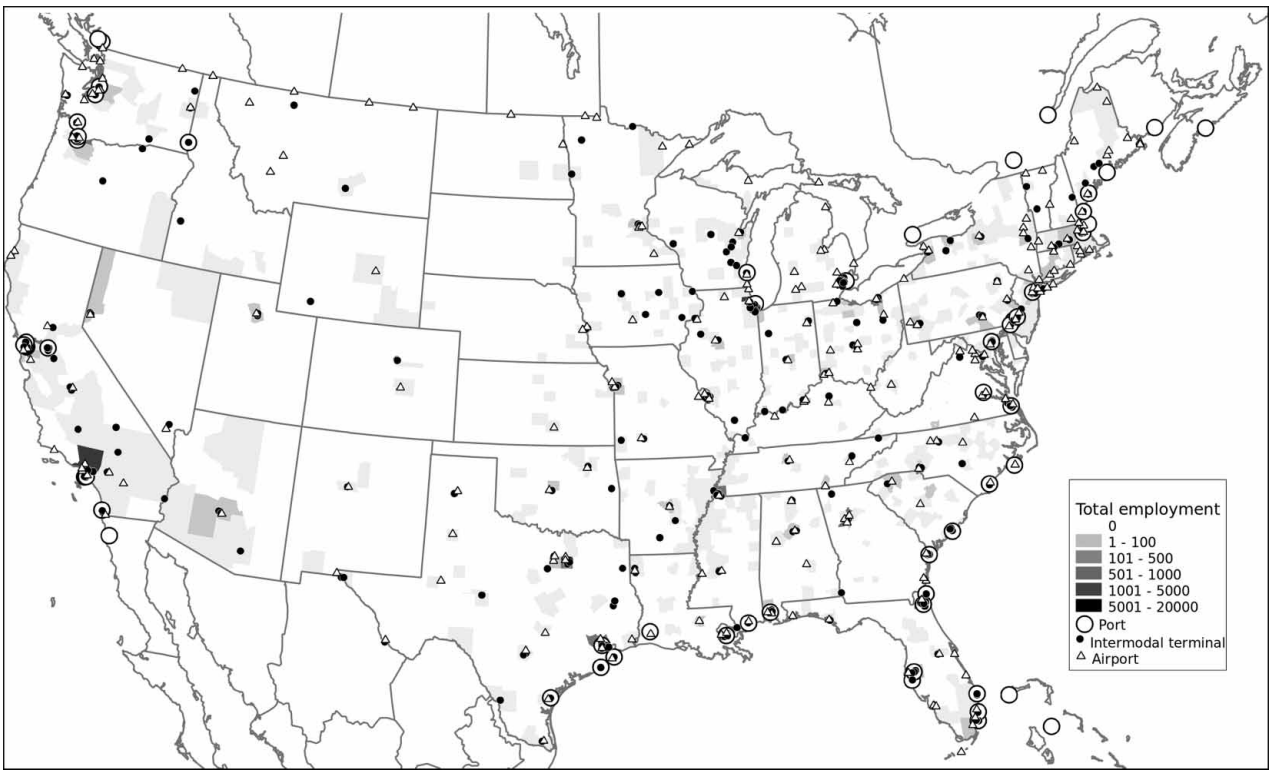

Fig. 1. *Total employment in general warehousing in 1974 by county*
Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

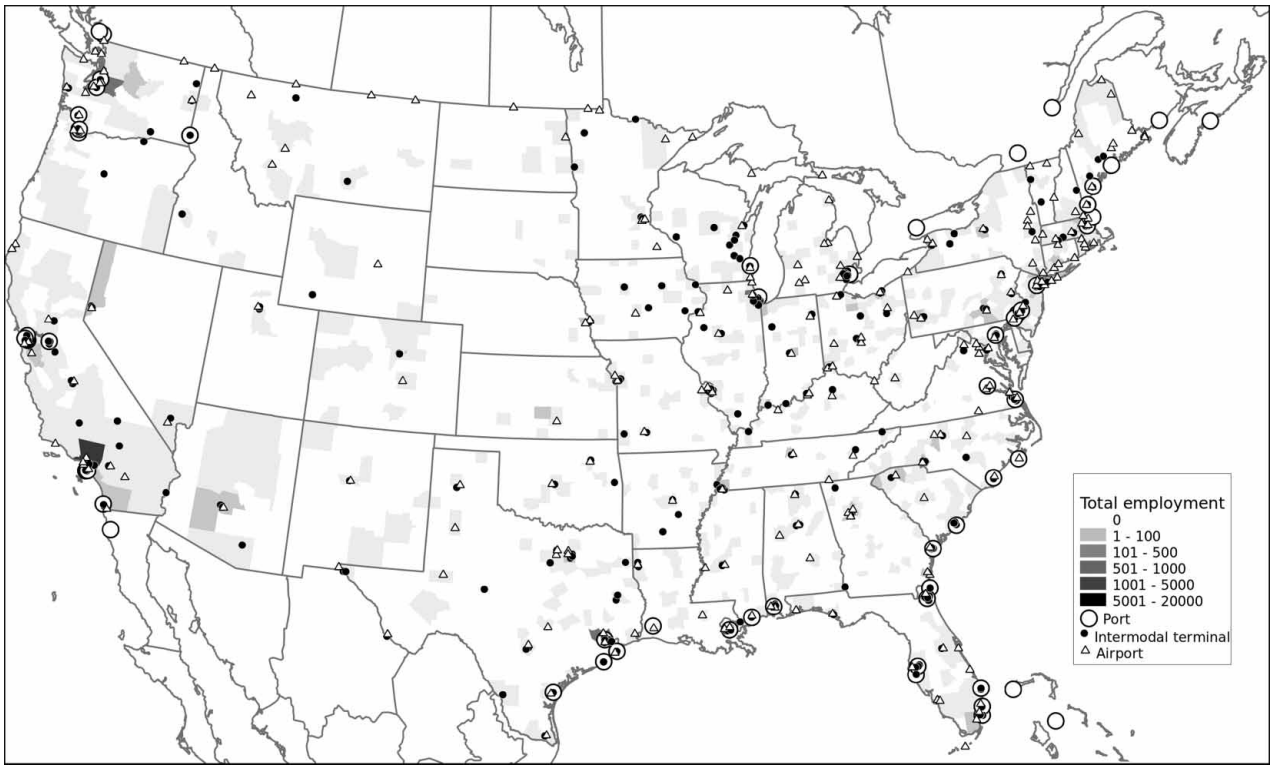

Fig. 2. *Total employment in general warehousing in 1984 by county*
Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

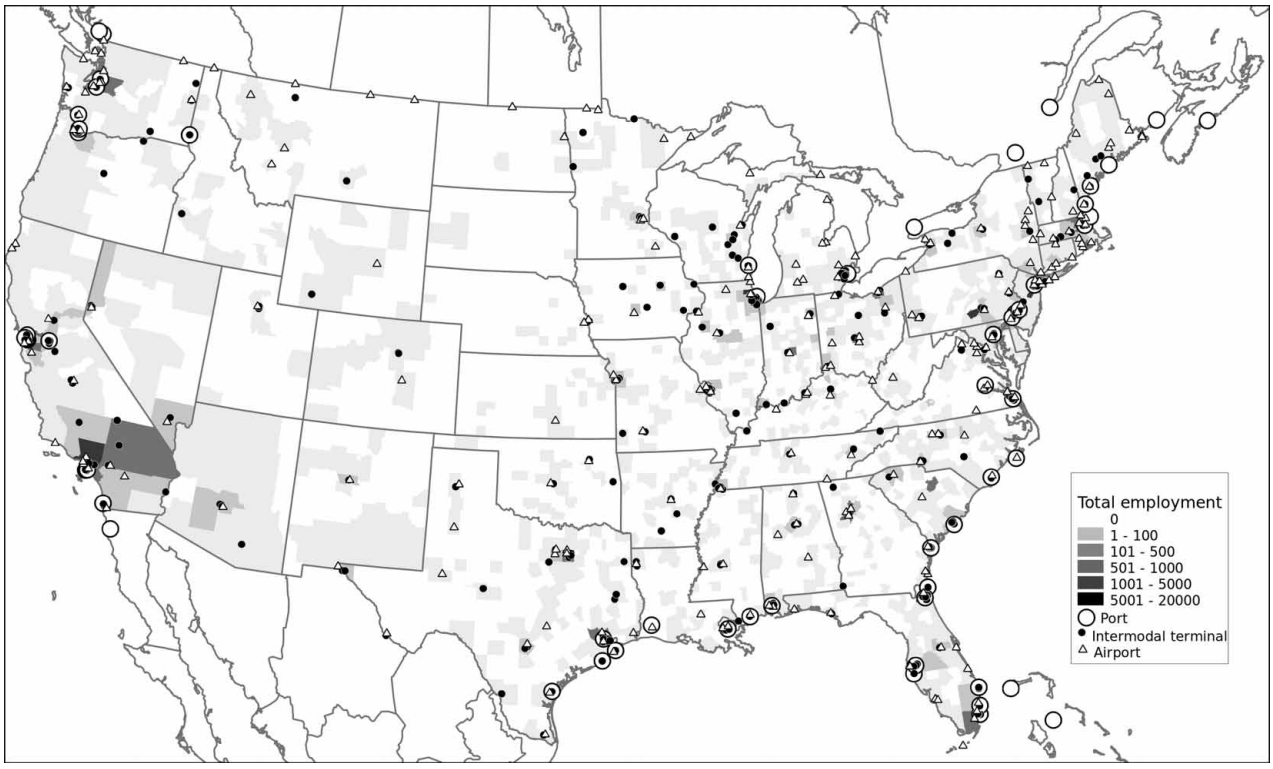

Fig. 3. *Total employment in general warehousing in 1994 by county*
Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

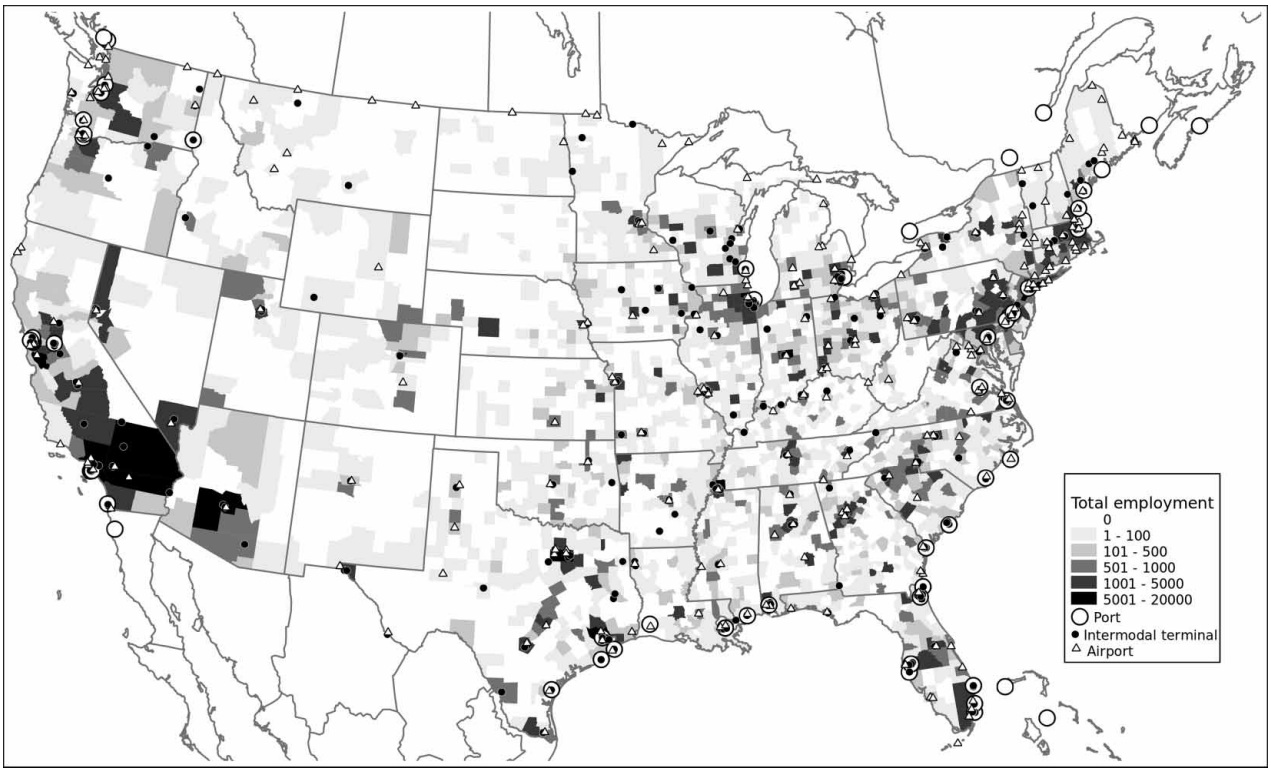

Fig. 4. *Total employment in general warehousing in 2007 by county*
Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

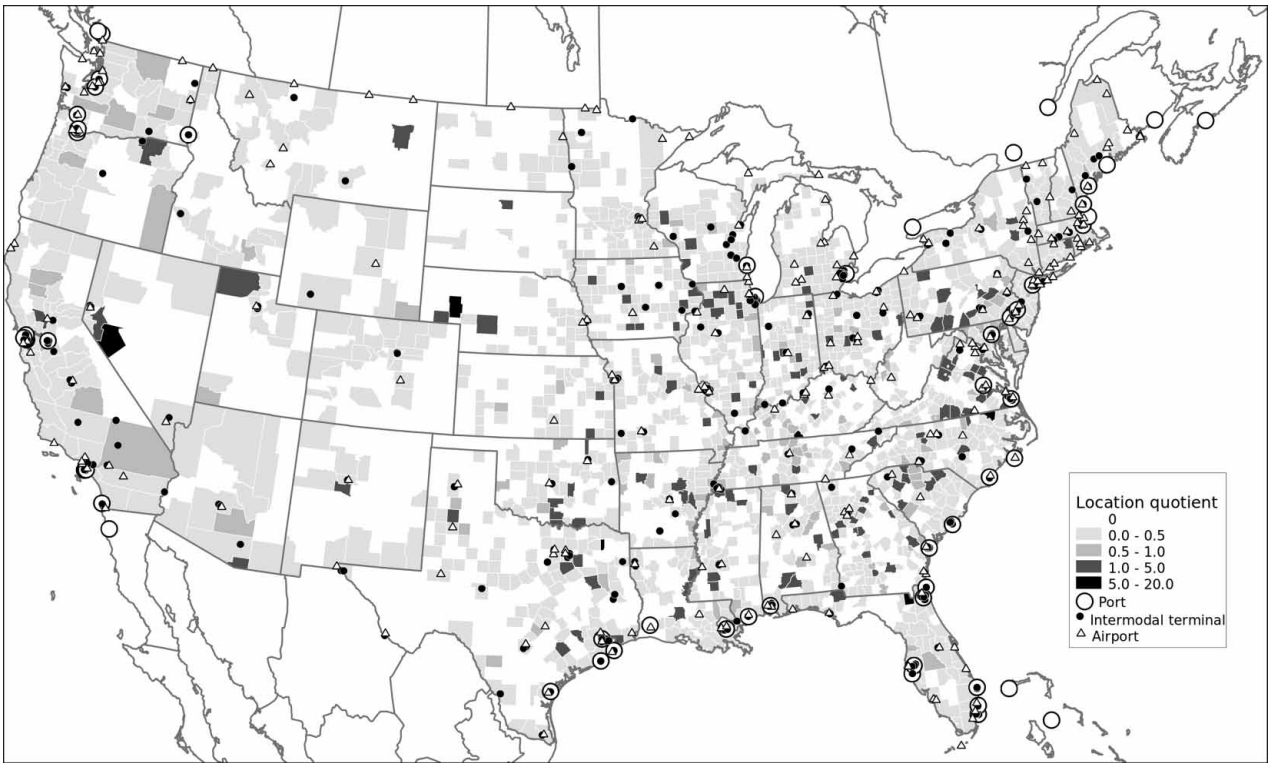

Fig. 5. *Location quotient for general warehousing in 2007 by county*
Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

With minor and temporary exceptions, the location quotient of counties proximate to ports remains consistently below 0.50 relative to total employment in this sector for the nation as a whole. This suggests that warehousing employment plays only a minor role in these counties' overall employment, though it does not indicate whether or not the role it plays is critical to the success of other economic activities in those counties.

Deconcentration. Even as total warehousing employment has grown, it has become more evenly distributed geographically. In 1974 warehousing employment (represented by shaded counties) is scarce and highly scattered (Fig. 1). By 1984 warehousing employment is growing on the east side of the Rocky Mountains and the Sierra Madre Mountains in Colorado and New Mexico and spreading into the Plains states (Fig. 2). In the following decade, warehousing expands geographically in a dramatic fashion. While continuing to grow along the West Coast and the mega-region that spans the East Coast from Boston to Washington, DC, rapid diffusion is evident in the Southeast, the Midwest and the Rocky Mountain states. By 2007, most non-mountainous areas of the United States are coated in a veneer of warehousing employment. Clear gaps in the Northeast and the West mirror the Appalachians and the Rockies, respectively. Additionally, there is a general tapering off as one moves west into the agricultural regions of the Plains. Over the last three decades warehousing has transformed from a scattered collection of islands to a fairly even distribution across the United States.

The results provided by a visual inspection of the map series are reinforced by regression analysis of the locational determinants of warehousing employment (Table 4), which suggest three findings, one of them spatial. The non-spatial findings are (1) the doubling of the coefficient for population density and (2) the persistent importance of per capita income. Indeed, the size of these coefficients makes them the overwhelming drivers of warehousing employment location. Roughly speaking, a 1% increase in either population density or income per capita is reflected in a 1% increase in warehousing employment. This finding significantly qualifies BOWEN's (2008) findings that within large municipalities warehousing establishments tend to locate in counties with greater access to highways and airports. As CHRISTOPHERSON and BELZER (2009) point out, the freight being moved in the United States has shifted from exports to imports. Thus, while there may be important localized trends toward locating in suburban and even ex-urban locations, especially for the largest establishments, the broader, driving impetus is proximity to the retail consumer base: denser, wealthier counties. This also suggests that the historical formation of cities at locations where the river of traffic deposited its load has been to some extent reversed: today the river seeks to deposit its load where there

Table 4. *Regressions against the log of employment for each sector*

	1974			1984			1994			2007		
General warehousing and storage												
(Intercept)	–8.89	***	(1.12)	–4.97	***	(1.20)	–9.82	***	(1.63)	–12.60	***	(3.00)
POPDENLOG	0.45	***	(0.02)	0.37	***	(0.02)	0.56	***	(0.02)	0.92	***	(0.03)
INCPCLOG	0.99	***	(0.15)	0.36	**	(0.15)	0.76	***	(0.19)	1.06	**	(0.33)
TAXRATE	–0.02	**	(0.01)	–0.01		(0.01)	0.00		(0.01)	–0.04	**	(0.01)
BA	0.03	**	(0.01)	0.02	**	(0.01)	0.06	***	(0.01)	0.05	***	(0.01)
HS	0.00		(0.01)	0.03	***	(0.00)	0.03	***	(0.01)	0.02	**	(0.01)
NONWHITE	0.02	***	(0.00)	0.01	***	(0.00)	0.01	***	(0.00)	0.01	***	(0.00)
FOREIGN	0.11	***	(0.01)	0.11	***	(0.01)	0.10	***	(0.01)	0.06	***	(0.01)
PORT	0.07	***	(0.01)	0.04	***	(0.01)	0.04	***	(0.01)	0.02	*	(0.01)
AIRPORT	0.01		(0.04)	0.02		(0.03)	0.06		(0.04)	0.10	*	(0.06)
INTERMODAL	–0.02		(0.03)	0.00		(0.03)	0.06	*	(0.03)	0.03		(0.05)
Adjusted R^2	0.412			0.394			0.549			0.526		
General freight trucking												
(Intercept)	–10.29	***	(1.33)	–18.44	***	(1.66)	–10.15	***	(1.83)	–3.40		(2.19)
POPDENLOG	0.86	***	(0.02)	0.75	***	(0.02)	0.87	***	(0.02)	0.85	***	(0.02)
INCPCLOG	1.39	***	(0.18)	2.26	***	(0.20)	1.28	***	(0.21)	0.51	**	(0.24)
TAXRATE	0.01		(0.01)	0.03	**	(0.01)	0.01		(0.01)	0.01		(0.01)
BA	0.04	**	(0.02)	–0.03	**	(0.01)	–0.02	**	(0.01)	–0.02	**	(0.01)
HS	0.03	***	(0.01)	0.02	***	(0.01)	0.00		(0.01)	0.01	*	(0.01)
NONWHITE	0.00		(0.00)	0.01	*	(0.00)	0.00		(0.00)	0.00	**	(0.00)
FOREIGN	0.08	***	(0.01)	0.08	***	(0.01)	0.04	***	(0.01)	0.05	***	(0.01)
PORT	0.01		(0.01)	0.03	**	(0.01)	0.03	**	(0.01)	0.03	**	(0.01)
AIRPORT	0.18	***	(0.04)	0.08	*	(0.05)	0.17	***	(0.04)	0.16	***	(0.04)
INTERMODAL	–0.04		(0.03)	–0.01		(0.04)	0.03		(0.03)	–0.01		(0.03)
Adjusted R^2	0.612			0.546			0.586			0.555		

Note: Standard errors are shown in parentheses. Significance *** < 0.001 < ** < 0.05 < * < 0.1.

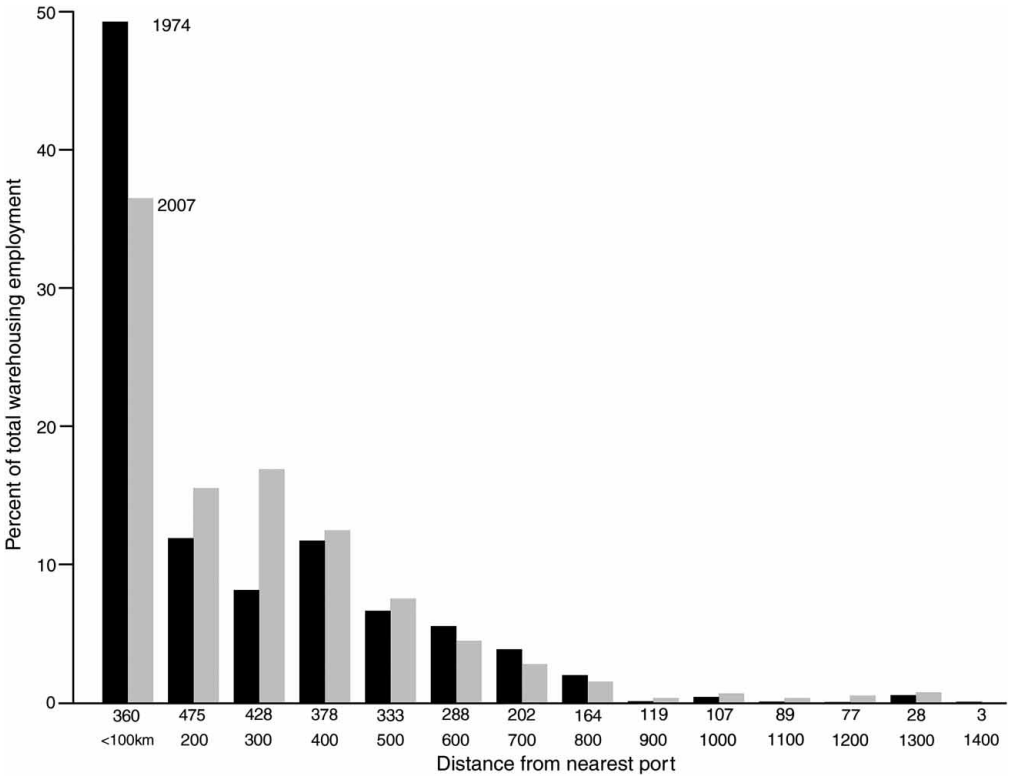

Fig. 6. Percentage of total warehousing employment by distance from nearest port (km). Numbers immediately under bars indicate the number of counties whose centroids fell within that 100 km-wide band in 1974. Year 2007 figures only differ by one in several categories

Sources: National Historical Geographic Information System (NHGIS) and *County Business Patterns* (CBPs)

are large agglomerations of potential consumers to take final delivery.

The third finding lies in the spatial relation of warehousing employment to logistics nodes. The regression results indicate that once one has accounted for warehousing's attraction to concentrations of the population and wealth, representing the localized function of warehousing, warehousing employment in that county would increase by almost 0.1% for every 100 km from the county to its nearest port in 1974. That is, for every 1000 km (620 miles) from a port (approximately the distance from New York City to Detroit), warehousing employment would increase by 0.7%, suggesting an increased need for warehousing goods in the centre of the United States to serve the national logistics network as this additional warehousing employment was not serving local populations. By 2007, the change over 1000 km had dropped effectively to zero (0.2%), implying that the geographical relation between ports and warehousing employment has weakened significantly. This suggests that relative to population, warehousing has indeed become more evenly distributed. This relation is also evident in a simple plot of the distribution of the percentage of total warehousing employment by distance from the nearest port (Fig. 6). This figure indicates that the percentage of total warehousing employment within 100 km of a port has dropped over 10 percentage points between 1974 and 2007 and employment between 600 and 900 km from ports has slightly declined. Meanwhile, the regressions indicate no significant relationship between warehousing employment and airports or intermodal terminals, except for a slight preference for locating away from airports in 2007.

Reconcentration. Though the overall trend in warehousing has been toward deconcentration away from the coasts, this movement has been accompanied by an evenly distributed inland reconcentration, or clustering. Two forms of concentration emerge after the mid-1980s: an inland band and distributed points.

The first type of concentration is a band of warehousing employment paralleling the coasts 200–300 km (roughly 200 miles) inland. This band is less evident on the West Coast, as the Cascade and Sierra Nevada Mountains press population closer to the shore and some inland counties occupy vast expanses of land. On the East Coast, however, one can identify a nascent band of concentration in 1984, particularly in Eastern Pennsylvania and the Carolinas (Fig. 2). By 2007 a clear band is evident just east of the Appalachian Mountains. This band also appears in the location quotient map for 2007 (Fig. 5), indicating that warehousing

is increasing both in absolute numbers relative to other counties in the United States and in importance to those counties' employment portfolios. Fig. 6 reinforces this observation. Almost half of all warehousing employment in 1974 was located within 100 km of a port. However, by 2007 this share had dropped to almost 35% with the bulk of the difference migrating to those counties located between 200 and 300 km from the nearest port.

The second form of concentration is the evolution of evenly distributed points of concentration in the middle of the United States. The general vacuum of warehousing employment in the 1970s and 1980s develops into a rather smooth coverage by the current day, but this layer is punctuated by fairly regular concentrations in the Southeast and Midwest in 2007 (once one has accounted for mountainous terrain).

Summary. Geographical change in the location of warehousing employment represents perhaps the most important element of the spatial fragmentation of port functions. It has expanded not only in volume but also in space. Following a see-saw motion, warehousing employment expanded out from its initial concentrations in 1974, became more or less evenly distributed across the United States by 1994 and then developed new concentrations by 2007. The most significant aspect of this contemporary reconcentration is that it has occurred along a band paralleling the coast, inland from the dense populations that line the oceans' shores and abutting the mountain ranges that lie within.

This inland band implies an intermediate geographical solution to the tension between centrality and proximity. While the drive for more central, low-cost locations appears to draw some warehousing inland, the primary driver of warehousing location appears to be proximity to goods' ultimate retail destination: wealthier and more populated counties. This does not necessarily indicate that warehousing locates in the wealthiest counties, but rather that some degree of proximity to higher income populations is important. Nor does this mean that all types of warehousing follow the same logic. These findings are consistent with both the possibility that warehousing locates in comparatively lower income counties proximate to higher income counties and the possibility that distribution centres do not locate near densely populated areas (BOWEN, 2008; CIDELL, 2010). It does, however, suggest that increased port activity generates warehousing employment not locally but inland.

Freight trucking

Freight trucking has grown in absolute numbers over the last forty years but has declined relative to overall employment. Freight trucking establishments are:

> primarily engaged in furnishing trucking and transfer services for a wide variety of commodities, generally palletized and transported in a container or van trailer, but including specialized freight that because of its size, weight, or shape requires specialized equipment.
>
> (US CENSUS BUREAU, 2007)

Though employment in trucking has increased from just over 1 million in 1974 to nearly 1.5 million in 2007, as a proportion of national employment, it has fallen from 1.62% to 1.26% (Table 2).

The regression (Table 4) shows that the location of freight trucking establishments, which includes dispatching centres as well as headquarters, behaves similarly to general warehousing: location is driven primarily by population density and per capita income. A 1% increase in population density will increase employment in general freight trucking by about 0.85%, almost a one-to-one relationship. While still demonstrating a strong relationship to per capita income, however, this has been dropping over time. From a height of an approximately 2.26% increase in employment for every US$1000 increase in per capita income, the correlation has dropped to roughly 0.5% for every US$1000. Thus, trucking establishments, like warehousing, locate proximate to goods' ultimate retail destination, densely populated counties, but they may be moving toward the poorer counties in those areas, presumably due to zoning and land costs. However, trucking and warehousing's divergent relationship to county per capita income suggests that future explorations of the location of freight-related activities should clearly distinguish between these two sectors.

At the margin, trucking employment also locates with an inter-temporally consistent relation to ports and airports, though not with intermodal terminals. For every 1000 km the average county is distant from a port, trucking employment increases by 0.3%. This is virtually constant across the last three decades. Distance from customs airports demonstrates a similar steady rate over time but is ten times stronger. Over 1000 km, trucking employment will increase by 3%. Trucking's relationship to intermodal terminals is indeterminate or non-existent. Taken together, these results suggest that trucking has not moved relative to transportation infrastructure during the period of containerization, though it does tend to locate farther away from ports and airports once population density is taken into account.

CONCLUSION

Since the advent of containerization, transportation firms have spatially fragmented the traditional port functions of transferring, storing and moving freight, thereby shifting the terrain of employment generated by the growth of trade. Technological advances have allowed

these companies to alter the flow of cargo so that much of it passes rapidly through the port proper, slowing down and 'depositing its load' at inland warehousing agglomerations before being redistributed. While capital-intensive and geographically demanding components of the network, specifically ports, have remained spatially fixed, less capital-intensive aspects, specifically warehousing and to some extent trucking, have expanded inland. The overall impact has been geographically to distend ports into their surrounding regions.

As the section on ports illustrates, while container traffic has increased many-fold in consistent locations, the centre of gravity for container traffic has – for the time being – shifted from the East Coast to the West Coast. This well-recognized shift (HALL, 2004; SLACK, 2004) is attributable to two primary factors: first, growth in trade with East and Southeast Asia has increased traffic on transpacific routes as they are the most direct; and second, ships have outgrown the Panama Canal, constricting transpacific trade's access to the East Coast. Additionally, the centre of gravity within each port range has remained within a single port complex. Such imbalanced growth has been dependent not only on port characteristics, such as channel depth, but also on access to large population concentrations within those ranges. Thus, since macroeconomic patterns of global trade and population density dominate the location of longshore work and increasing automation is reducing terminals' reliance on longshore employment, efforts to increase container throughput no longer appear to have a role to play in boosting employment in port cities.

The fragmentation of port functions is evident in warehousing's inland migration. Employment in the sector has increased in absolute terms but remains tied primarily to its customer base, suggesting that large cities are now independent of the mechanical breaks in the logistics network rather than being generated by them. However, the possibility that mechanical breaks in the movement of freight can generate or expand urban agglomerations remains. Pulled inland by lower operating costs and network centrality and pulled toward wealthier and denser agglomerations by firms' customer base, warehousing has developed an inland band of activity and is employing ever greater numbers of workers. This suggests that there is a 'window of opportunity' for localities that lie within this band (JACOBS and NOTTEBOOM, 2011).

Development strategies focused on warehousing promise direct economic development opportunities. However, research suggests that most of these jobs offer limited advancement and income (BENSMAN, 2008; CHRISTOPHERSON and BELZER, 2009; HALL, 2009). Therefore, to create greater opportunities, localities would have to develop more complex strategies that take advantage of the growth of localization trends in production to attract and build on the final, value-added stages of the production process. They may even be able to work backward along the supply chain from distribution to incorporate progressively earlier stages of production and perhaps lure later stages of manufacturing back to the United States. On the contrary, freight trucking appears to offer little in the way of economic development potential. Despite – or perhaps reflecting – a declining predilection to locate in higher-income counties, the deregulation of trucking has resulted in low incomes, long hours, economic vulnerability and often unsafe working conditions for truckers (BENSMAN, 2009).

In sum, containerization has contributed to the spatial fragmentation of port functions by moving the mechanical break in the 'river of traffic' inland from the land–maritime interface. As a result, traditional port functions other than longshoring no longer rely on proximity to ports, but rather on their customer base. Thus, the port's historical role as an engine of local employment growth appears to be drawing to an end.

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