Relationship of Regional, Freight, and Intermodal Market Access to Industry Location and Productivity

Glen Weisbrod and Jenna Goldberg
EBP US, Inc., Boston, MA

Manuscript version; later published in Transportation Research Record, November 2022

Abstract. Although a significant body of research has focused on employment agglomeration at an urban level, this paper presents a broader view that also includes new empirical research on wider regional and intermodal access and its economic implications. The analysis shows how business clustering (employment agglomeration) can occur at different scales and in different forms, reflecting a range of needs to access local and regional populations, suppliers, and customers, as well as intermodal gateways that provide access to broader national and global markets. These different types of access have broader economic development and productivity implications that are particularly important for transportation planners who evaluate proposals for freight and passenger modal investments connecting communities and intermodal facilities. To address these issues, the paper brings together three complementary perspectives: (a) transportation planning literature that distinguishes types of transportation investment and plans; (b) site location literature that defines business location decision processes and their spatial scale; and (c) economic research that provides a basis for defining scale economies and productivity effects. It presents results of a new U.S. study that develops statistical relationships between types of access and industries in relation to their relative concentration and productivity at a county level. The results show the importance for transportation planners to consider freight access as well as customer and worker access. They also indicate the potential for decision bias if project prioritization and cost–benefit analyses fail to consider the full range of spatial scales relevant for assessing market access. The article discusses implications of these findings in terms practical applications for transportation investment planning, and it highlights remaining needs for further research.

Transportation planners operating at the state or regional level often need to evaluate plans for improving freight and passenger connections between communities as well as ground connections with intermodal facilities. These changes in connectivity can be particularly important for regions with evolving population and economic patterns. In that regard, there has been increasing attention paid to the role of transportation corridor investments in expanding the accessibility of areas to surrounding markets and intermodal terminals, and resulting regional economic consequences. However, much of the past attention on economic consequences has focused on urban business agglomeration rather than broader regional-scale access and connectivity for freight and passenger travel. There is thus a remaining need for transportation planners to better differentiate the economic benefits and impacts of different kinds of transportation investments in various locational contexts.

Overview

This paper addresses these issues by examining how three distinct lines of research—transportation, regional development, and economics—can provide insight into various dimensions of transportation access and its economic consequences. An important aspect of this analysis is the distinction made between types of access that are relevant depending on the type of transportation investment. This includes measures of access for local labor markets, same-day passenger travel, just-in-time freight delivery, and broader access to airports, intermodal rail terminals, and seaports. The paper then presents results of a new U.S. study that analyzes the statistical relationships between these different types of access and their resulting impacts on concentration and productivity of specific industries. These findings can have practical applications for improved transportation investment planning and help to highlight directions for future research.

Combining Research Perspectives

This paper seeks to bring together three complementary perspectives that together define the application of access concepts in transportation planning: (a) transportation planning literature which defines the nomenclature and classification for distinguishing different types of transportation investment and plans; (b) site location literature which defines business location decision processes and their spatial scale; and (c) economic research which provides a basis for defining scale economies and productivity effects. We show how these three lines of research can together provide more nuanced and insightful findings to inform transportation planning and investment decisions.

Role of Access from the Transportation Planning Perspective

The transportation planning process provides a framework for evaluating access that is necessary for infrastructure investment. This starts with the distinction made by transportation planners today, between (a) effects on saving time and/or cost for existing travel patterns, and (b) effects on expanding possible travel patterns by enabling access to broader areas and opportunities. The latter (access) role was historically important, as the U.S. economy developed following the expansion of markets enabled by the Erie Canal, transcontinental railroad, and interstate highway systems. Although market access impacts have long been considered in transportation planning, the advent of travel demand models and benefit–cost analysis have more narrowly focused attention to investment decision making based on traveler time and cost savings. More recently, though, the role of improving market access and its effects on enhancing productivity has again gained consideration in the context of wider economic benefits for transportation investment evaluation (1–3).

Transportation planning and decision making has sought to match investment in different types of modal facilities (i.e., roads, rail lines, airports, and water ports) with the categories of user demand to which they are best suited, using "trip purpose" such as freight delivery, commuting, business passenger travel, and tourism/leisure travel to differentiate needs (4). Mode–purpose combinations have a systematic relationship to travel distances that indicate market access ranges. For example, the definitions of labor markets and freight delivery market relate to distinctly different distance ranges; the former typically involves travel times under 1 h whereas the latter may involve travel times of 3 h or more. (See later discussion of market size thresholds.)

As transportation planners often rely on network models for ground access measurement, they can see airports, rail freight terminals, and water ports as network nodes that operate as "intermodal gateways," providing access to broader national and international locations. From that perspective, network connectivity is the process by which links are provided (or enhanced) to expand the effective breadth of markets for labor, freight delivery, and other economic or leisure activities. We can thus view transportation investment effects on access to those markets as dependent on the types of modal facilities and trip purposes that they serve. This view is today reflected in the large volume of multi-modal plans, freight plans, and rail plans being completed by U.S. states and MPOs, that often distinguish investments in relation to key commerce corridors, freight corridors, commuting corridors, and intermodal terminal access.

Role of Access from the Perspective of Business Location

Business site location decisions have long been a central concern in the economic development field, which seeks to maximize growth of job opportunities and wages. Economic developers recognize that these goals are tied to increased productivity and expanded markets, which can be enabled by transportation system access. The site location literature follows these issues to provide insight into how business location and clustering decisions vary among industries and at different spatial scales.

Site location research commonly ties business site location to a decision process with two elements. The first is regional scale—considering the regional availability of workforce, suppliers, and customer markets, as well as unit operating costs (for energy, labor, transportation, and taxes). The second element is local scale—selecting a site location within that region based on requirements for land, ground and intermodal transportation access, utilities, and related amenities.

The role of access for both freight and labor is demonstrated by Area Development magazine's annual survey of national corporate executives, which shows the top ten decision factors in U.S. industrial site location. They include three regional access considerations: highway accessibility, availability of skilled labor, and proximity to major markets (5). These location factors apply for "traded industries" (e.g., manufacturers), which produce and sell products across regions and therefore are loca-tionally mobile—able to choose a regional location that optimizes their revenue and profitability. The importance of highway locations for manufacturing industry sites has also been identified in several European studies (6, 7). In contrast, long-distance highway access is not as strong of a factor for "local-serving industries," which are in contrast to traded industries as they need to locate in areas where they can best access the immediately surrounding population base (8). There is extensive research documenting the importance of regional-scale access for specific traded industries. This includes studies in the following areas:

- *High-Tech Clusters.* In the U.S., there has been particular attention to the clustering of high-tech industries, such as computer/software and biomedical/pharmaceutical industries. High-tech industries typically cluster in specific metropolitan areas where they can access a sufficiently large workforce to find specialized skills, along with access to university research facilities (*9*, *10*). The statistical relationship of high-tech employment with access to a large-scale population base, a major university, and a major airport has also been documented (*11*). These three attributes correspond to agglomeration benefits of labor pooling/matching, knowledge spillovers, and access to collaborators. High-tech clusters are generally defined at a metropolitan scale, as illustrated in the example of the life sciences clusters shown in Figure 1. Another line of research has shown that, within those met-ropolitan areas, high-tech businesses tend to locate in areas with public transportation access (*12*).

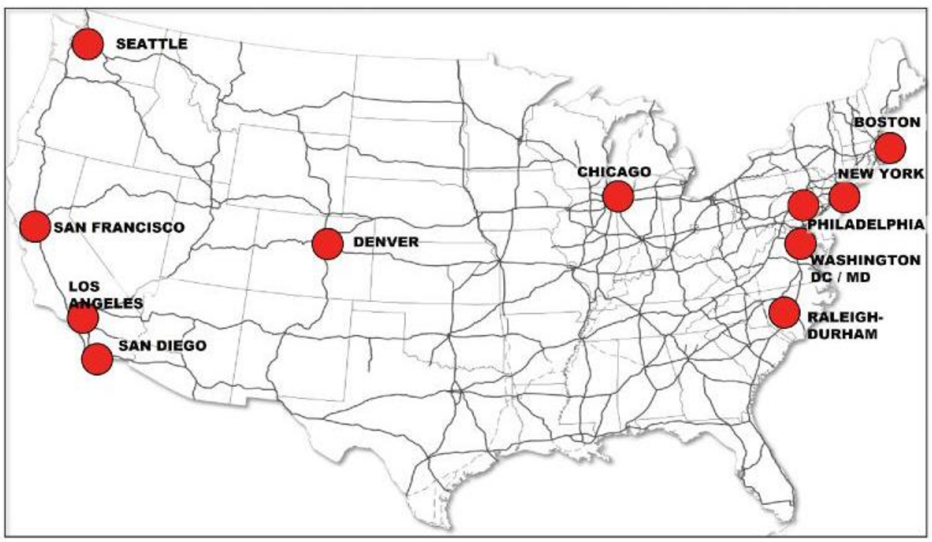


Figure 1. Top U.S. metro area life sciences clusters (pharmaceutical + biomedical devices).

Note: Circles denote metropolitan areas rated as leading life sciences clusters (***Source***: JLL 2020 Life Sciences Real Estate Outlook) and ''top biopharma clusters" (***Source***: Genetic Engineering and Biotechnology News, April 2021).

- *Intermodal Access for Manufacturers.* There is broad body of research on the importance of intermodal terminal access for manufacturers, which represents gateways to broader national and international freight markets. This includes access to intermodal truck/rail terminals (*13*), as well as air and marine freight terminals (*14*). Several studies have focused on the importance of airports to manufacturers and distributors of products with a high value/weight ratio, as they provide access to global-scale markets (*15–18*). Others have developed county-level measures of freight accessibility differentiating between air, rail, and maritime gateway access (*19*, *20*). The roles of modal terminal access in affecting the concentration of various industries have also been examined (*21*). A related line of studies documented the role of freight accessibility in enabling specific spatial concentrations of both regional logistics and foreign trade-related activities (*20*, *22*). Trade-oriented logistics clusters reflect scale economies where ground transportation networks connect consumer and supply chain markets to global freight markets via intermodal air and sea facilities (23). They can include both “near dock” and “inland port” or “inland terminal” facilities (*24–26*).

- *Same-Day Manufacturing Supply Chains.* The confluence of information technology for inventory control, along with highway network development, has also enabled scale economies in serving wider markets for same-day and overnight delivery. A prominent example is the southeastern U.S. automotive cluster, an area centered around the Nashville–Atlanta–Birmingham triangle. It features many automobile assembly plants located along major interstate highways, along with parts suppliers located along highway routes that enable “same-day” delivery to those assembly plants (*27–29*). (See Figure 2). This form of regional clustering along highway corridors enables firms to more reliably source parts, reducing buffer stocks and associated logistics costs. The spacing of facilities also helps minimize generation of traffic congestion as well as competition for workers (which would bid up wage rates).

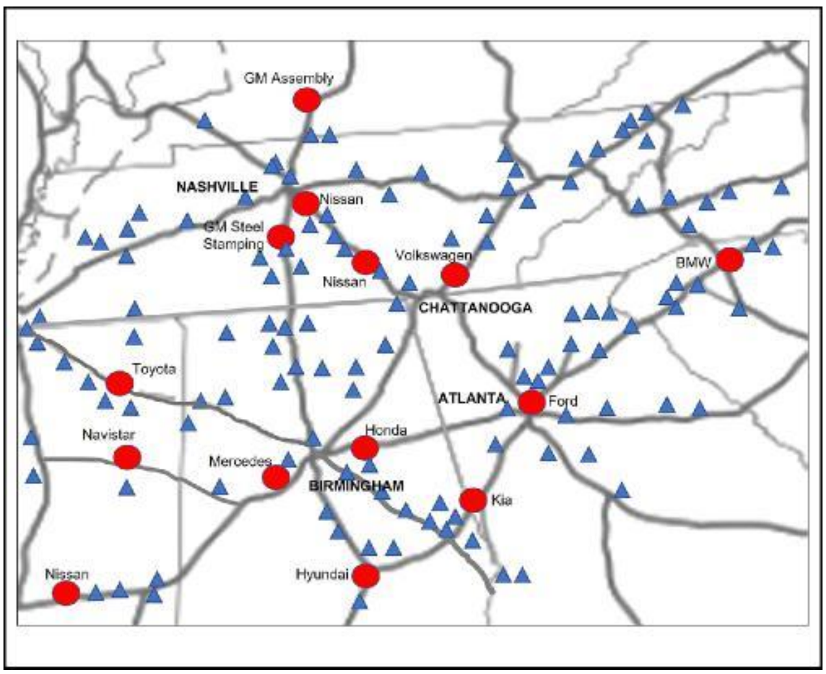


Figure 2. Southeast U.S. automotive supply chain cluster.

Note: Circles denotes automotive assembly plants (*Source*: Google maps, 2022); Triangles denote automotive parts suppliers (*Source*: Driving Workforce Change, The U.S. Auto Supply Chain at a Crossroads, undated).

- *Regional Distribution Centers.* Fueled by the expansion of e-commerce, massive warehouse clusters have developed in regions around Los Angeles, New Jersey, Pennsylvania, Dallas,

  Atlanta, and Chicago. This form of development builds on integrated supply chain management that utilizes information and communications technologies to enable regional distribution centers that can utilize scale economies to serve wider delivery markets (*30*). This has been characterized as “logistics sprawl” because these distribution clusters are further from urban centers than older, local warehouses (*31*). An example is the cluster of distribution centers along a 120-mile stretch of I-81 in Eastern Pennsylvania. These facilities provide deliveries to retail chain stores as well as e-commerce deliveries. Illustrated in Figure 3, this cluster is situated along a corridor where same-day round trips can be made to four large metropolitan areas on the east coast. Although the major metro areas are all served directly by I-95, that has become a congested corridor. Some distribution centers are still located along I-95, but the distribution industry trend has been toward larger facilities that can serve multiple metro areas, and the less congested I-81 corridor has since emerged as the preferred location for these newer and larger facilities.

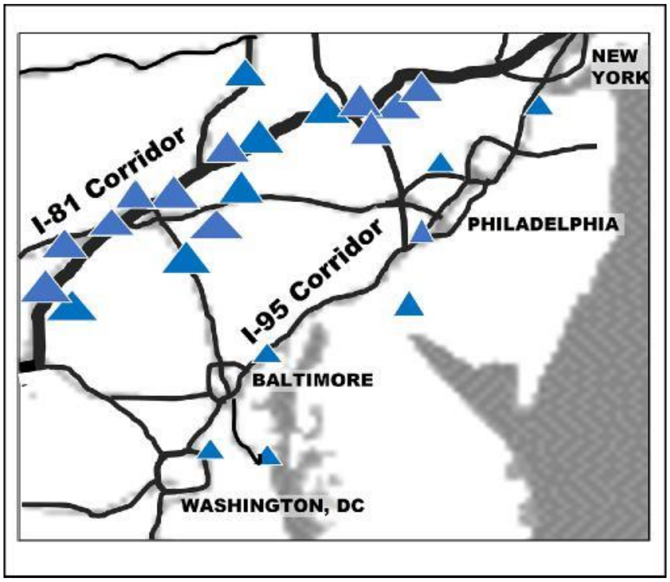


Figure 3. Cluster of regional distribution centers, primarily along I-81 corridor in Pennsylvania.

Note: Triangles represent regional distribution centers for retail chains and e-commerce.
Source: Data points were derived from the Google Maps display of distribution centers.

- *Tourism and Visitor Support Industries* depend on customer access to their services. A variety of studies have documented the role of airports in providing market access for national and international tourism industry development (*32–34*). Tourism is considered a traded industry in that it involves interregional commerce bringing an inflow of money to a region, though in this case the customer comes to the producer, in contrast to manufacturers who normally deliver the product to the customer.

Taken together, these examples show how various types of traded industries cluster to maximize access to relevant labor, supplier, and customer markets, as well as sources of technology knowledge. The various types of clusters differ in relation to spatial scales and densities, reflecting a range of attraction and dispersion productivity factors that depend on transportation networks and facilities. These factors are discussed next.

Role of Access from the Perspective of Economic Evaluation

The economic research literature on "agglomeration effects" evaluates how areas with higher concentrations of business activities can also have higher productivity. These effects draw on both scale economies in accessing surrounding markets (urbanization effect), and scale economies in drawing on similar and complementary businesses located nearby (localization effect).

One line of research on agglomeration has focused on regional area effects—showing how the productivity of specific industries at a state or metropolitan level relate to the density, scale, and connectivity of activities (35, 36). Other studies have focused on agglomeration at a finer zone level, assessing the concentration of employment among UK wards or U.S. census tracts. This latter line of research has highlighted the effects of proximity to similar firms in explaining productivity effects. Graham (1) developed the concept of "effective density"to capture the combined effects of a zonal concentration of industry activity and a gravity model function that captures industry concentration in surrounding zones weighted by travel time proximity. Studies have shown that zones with a higher effective density of employment in specific industries have relatively higher levels of value added and wages per capita (37–39).

These related lines of research are important in demonstrating that business agglomeration reflects transportation access and is associated with positive impacts on productivity. It makes the case that improving transportation access can have wider economic benefits. However, there are two notable limitations to the application of this research for transportation planning processes. First, studies that measure impacts at a fine level of spatial detail can best capture local urban clusters of producer services (office districts) and retail/consumer services (shopping centers and districts). That level of zonal analysis is less capable of directly capturing industrial and supply chain agglomerations that stretch out to follow highways or locate around intermodal terminals. It also cannot discern dispersion economies—that is, productivity gains associated with firms locating to avoid congestion for time-sensitive truck deliveries or spacing to serve multiple supply chains. These limitations most directly apply to manufacturing and distribution industries.

Second, although these studies statistically relate business agglomeration to productivity, they generally cannot discern industry-specific causal effects. For instance, business agglomeration can in theory reflect any combination of urbanization, localization, or knowledge economies, though in practice some factors may be more or less important for a given industry. Some economic research studies have sought to isolate the differing industry-level incidence and causal roles of localization, urbanization, and knowledge economies (40). Others have attempted to distinguish differing roles of physical density, residential market access, and employment proximity within an urban area (39). The previously discussed business location literature can carry us further in providing insight into causal effects and limiting effects that apply to passenger movement, freight movement, and intermodal connectivity at different spatial scales.

A General Model

From the preceding discussions of research literature, we can identify three organizing principles:

(1) *Agglomeration occurs at different spatial scales.* There are at least seven different patterns of business clustering and agglomeration effects that are transportation dependent, as shown in Table 1. This table covers the traded industries examples previously shown, and adds two major categories of local-serving industries. Although this typology is not exhaustive, it clearly demonstrates that there are widely varying combinations of business cluster scale, spacing, and location relative to transportation networks and facilities.

(2) *Business agglomerations reflect efforts to optimize various attraction and dispersion factors that are tied to transportation access.* This typology of clusters reflects attraction, dispersion, and clustering factors that can affect productivity. It was originally introduced in NCHRP Report 786 (*41*). We have expanded the range of cluster types and factors to provide a more comprehensive summary in columns 2–4 of Table 1. These factors are tied to scale, concentration and/or dispersion economies in accessing some combination of supplier markets, labor markets, customer markets, and/or learning economies.

(3) *The roles of access factors are differentiated by spatial levels and transportation mode/purpose.* The spatial levels are local market (travel within a labor market or metropolitan area), regional market (same-day travel), and intermodal market (access for long-distance travel). Each can also be differentiated by mode/purpose: commuting, freight delivery, personal/leisure, and business travel.

Table 1. Illustrative Categories of Industry Clustering and Agglomeration Effects

Cluster Type	Maximizing Factors (urbanization economies)	Cluster Factors (localization economies)	Minimizing Factors (dispersion economies)
High Tech: Metro-scale, Knowledge Clusters (e.g., biotech, computer software products)	In metro areas with access to universities, airports, and a large base of educated workers with specialized skills	Locate with similar firms to gain knowledge spillovers (technology information sharing)	May avoid high rise office districts to reduce real estate cost
Manufacturing: Peripheral, Corridor Clusters (*e.g.*, industrial parks, districts, corridors)	In regions where they can maximize truck access to parts suppliers and buyers (including assembly plants)	Concentrated at highway access routes to reach regional markets, rail connections (to national markets), or optimize same-day truck deliveries for just-in-time manufacturing	At the periphery of metropolitan areas and spread along intercity corridors to avoid congested roads
Bulk Resource Processing Clusters (e.g., agriculture, metal/ mining products)	In rural areas with access to material resources	In the vicinity of rail/marine bulk loading facilities for national and global distribution	At periphery or outside urban areas to minimize land cost and road congestion
Distribution/Logistics Clusters (e.g., warehousing, distribution centers)	In and around major metro markets with intermodal terminals, to maximize reach for regional customers + global markets	Concentrated around intermodal terminals (especially airports) and highway intersections to maximize regional and global connectivity	At the periphery or adjacent to major metro areas to maximize available land and minimize land cost
Visitor Services Clusters (e.g., lodging, meals, recreation)	In areas that have visitor attractions along with a large regional population base for day trips	Largest clusters are near visitor attractions that are served by airports for access to national and international markets	Dispersed around the vicinity of the visitor sites or along access corridors to minimize congestion
Producer Services: Office Clusters (e.g., finance, insurance, business services)	In metro areas that have a broad regional workforce with required education and skills	Concentrated in office districts to maximize knowledge spillovers (learning benefits); at urban core and outlying transport nodes to maximize labor market reach	
Consumer Retail Clusters (shopping districts and centers)	Most highly concentrated in metro areas with a large surrounding customer base	At major transportation network nodes and clustered to create and share greater market power – with differentiated offerings	

Source: based on [41], *with additional categories added*

Following the literature review and previously cited organizing principles, we can expect both employment concentration and wage rates for each industry "i" to be a function of market access in terms of the following dimensions:

$$\textbf{Emp Concentration(i)}_i \textbf{ or Wage Rate(i)} = \textbf{\textit{fn}} \textbf{ (Local Market}_{P,F}\textbf{, Regional Market}_{P,F}\textbf{, Intermodal Market}_{P,F,T}\textbf{)}$$

where
Local Market = opportunities within a metropolitan, micropolitan or rural labor market area;
Regional Market = opportunities reachable by ground access for same-day business, leisure, or

freight delivery trips; Intermodal Market= destinations reachable by transfer from ground to air, water, or rail transportation networks.

P=population access (for labor market or customer markets), F=freight access (for industry supplier or buyer markets), T= terminal type (for access to broader national and global markets via air, water, rail).

Empirical Research Design

Regressions

Our empirical analysis sought to test the preceding general model, drawing explanatory factors from the three research perspectives discussed earlier: (1) transportation planning literature on the importance of distinguishing modal connections and freight/passenger trip purposes; (2) business location literature on the importance of regional markets and intermodal connections; and (3) economics literature on the usefulness of measuring both employment and income impacts. We recognize that there has been substantial prior research on the economic agglomeration patterns among and within local market areas, but far less attention to the roles of regional and intermodal market access in affecting the clustering and productivity of economic activities. Likewise, there has been substantial research on urban job and workforce access, but far less attention to freight and supply chain access. So we designed regressions to help fill this gap.

We developed two sets of regression models; the first predicts the magnitude of zonal employment in each industry, whereas the second predicts zonal average wage for employees in each industry. We test the preceding general model to assess the statistical relationships of both employment and wages (by industry) to the three classes of market access: local-scale ground access, regional-scale ground access, and intermodal access. These spatial scales of market access correspond to different types of transportation networks. To further improve applicability for transportation planning, we distinguish between types of industry clusters most dependent on passenger access for workers and customers (e.g., office, retail, high-tech R&D, and visitor clusters), and those that are most dependent on incoming and outgoing freight delivery access (e.g., manufacturing, distribution, and logistics clusters). We also account for additional explanatory factors such as workforce education level.

This analysis requires the development of economic and access databases that can span both urban and rural areas over large distances, with sufficient industry detail to distinguish variation in dependence on different kinds of access.

Spatial Scale and Granularity

The regressions are estimated with a dataset comprising 3,053 counties within the contiguous 48 U.S. States that are directly interconnected via highway and rail systems; these represent the study zones. Counties in the U.S. define most small metropolitan areas, micropolitan areas, and rural labor market areas. They are building blocks for larger metropolitan areas. Commonly, each county has a principal city that serves as the county government seat and center of economic activity. For each county, our dataset separately measures employment and mean wage for each of 316 industries—representing 4-digit NAICS codes. The county economic details are derived by IMPLAN using data from the Bureau of Labor Statistics, Bureau of Economic Analysis, and Census Bureau (42). Local population is measured by block group using the American Community Survey (ACS), and local employment is measured by the Longitudinal Employer Household Dynamics (LEHD) dataset.

There are reasons why this level of spatial granularity is desirable. Fundamentally, there is a data tradeoff between economic detail and spatial detail. Although we can get highly detailed employment and wage data for all counties across the U.S., the available data sources withhold industry and wage detail when we drop to finer spatial scales. In this case, we need a high level of industry detail to distinguish the specialized industries that most require large labor pools, large regional delivery markets, and/or access to specialized air, rail, or container port terminals. Furthermore, the scale of same-day delivery markets and the service areas for intermodal terminals are sufficiently large that those markets typically span many counties. Thus, the county level of observation is sufficient to capture major variations in the size and scale of these types of market access, while enabling the required industry-level detail.

A negative consequence of relying on county-level data is that it misses the highly localized spatial clustering of office and retail activities that have already been well identified in prior studies relying on finer-scale urban zonal systems. Those prior studies, discussed earlier, show the importance of physical density and effective density for accessing similar businesses nearby. This is offset by the advantage of county-level detail for measuring the wider-scale clustering of manufacturing and distribution activities. As discussed in the literature review and illustrated in Figures 2–3, these kinds of activities do not cluster in dense configurations as common for offices and retail stores. Rather, they are attracted to certain regions of the county and locations along specific highway corridors and intersections. These effects can best be captured using wider-scale but coarser zones. The county scale is also helpful in showing effects such as the role of a highly educated labor market in attracting high-tech industries to a region.

In fact, a pitfall of overly fine zonal detail is that it introduces "noise" into the statistical analysis for specialized manufacturing and distribution activities. This is illustrated by the problem of trying to explain differences in industrial location patterns at the census tract level, as we commonly find cases in which two adjacent census tracts have similar access yet one has a major industrial

park and the other has no industrial activity. The reason for this disparity may be localized factors affecting industrial siting, such as zoning, availability of vacant land, availability of utilities, and/or highway turnoff locations. When we move to a larger spatial scale such as counties, the need to also account for those localized factors disappears as nearly all counties will have some places not subject to these limitations.

Measurement of Access

Whereas many prior studies focused on urban-scale access effects, this study examines broader region-scale and intermodal-scale effects that reach out hundreds of miles. We measure local and regional market size using census population data and LEHD employment data for census block groups within 30, 40, 50, 60, 120, 180, and 240 min of road drive time from the center of the largest city in each county. The drive times are based on the ArcGIS Street Map network using HERE data. The drive-time polygons were matched to census block groups.

For intermodal market access, we calculated drive times to the closest commercial airport, commercial intermodal rail terminal, and commercial water port, based on the above-cited transportation network data and intermodal terminals identified in the National Transportation Atlas Database (NTAD) provided by the Bureau of Transportation Statistics (BTS). We limited airports to those classified by the Federal Aviation Administration (FAA) as medium or large, based on volume of activity. These are the top 64 U.S. commercial service airports in relation to enplanements. We limited water ports to the top 125 in relation to tonnage. Depending on the industry sector, the closest water port shifts to that which provides applicable bulk or container shipping services.

We recognize that there are some urban areas that are well served by multiple airports, multiple water ports, or multiple intermodal rail facilities. For those areas, the simple decision rule of selecting the closest major facility represents a source of imprecision. However, that is unlikely to generate major bias, as the primary objective of our analysis is to distinguish between areas of the U.S. that are well served by proximity to large intermodal terminals and those that are not. Those areas that are well served by multiple terminals will tend to have good access ratings regardless of which local terminal is selected.

For all types of intermodal terminals, travel times were calculated from the center of the largest city in each county using ArcGIS/HERE network data. To represent the roles of intermodal facilities as gateways to broader markets, we attached corresponding BTS data on annual passenger and cargo volumes for airports, and cargo volumes for water ports. Travel times to the nearest inter-modal terminals varied widely, extending as long as 5 h for the nearest major airport, and over 10 h for the nearest container rail terminal or container port.

Defining Industry Groups

For the analysis, we utilized the available industry detail to assemble industry categories corresponding to the cluster types previously shown in Table 1. The classification of industries draws on BEA input–output data to show the relative labor and freight transport dependence of individual industries, and BTS Transportation Satellite Accounts to distinguish truck, rail, air, and water modal dependence. The industry category definitions are listed in Table 2. We omitted analysis for government, education, and utilities as the location of those activities are generally not driven by economic markets.

Table 2. Assignment of NAICS Industry Groups to Cluster Categories

(1) High-Tech/High-Value Manufacturing (knowledge clusters; ship products mostly by air)
- 3254 Pharmaceutical and medicine manufacturing
- 334 Computer, electronic and peripheral equipment manufacturing
- 3364 Aerospace product and parts manufacturing

(2) Miscellaneous Manufacturing (all other production; ship products by truck and rail container)
- 112 Animals and Fish manufacturing
- 312 Beverages & Tobacco manufacturing
- 313 Textiles manufacturing
- 315 Apparel manufacturing
- 3255 Chemical products manufacturing (excl. pharma and basic chemicals)
- 332 Fabricated metal products manufacturing
- 333 Machinery manufacturing
- 335 Electrical Equipment manufacturing
- 336 Transportation equipment & parts (excl aerospace)
- 337 Furniture, 339 Miscellaneous manufacturing

(3) Bulk Products (ship mostly by rail and water transport)
- 111 Grains
- 21 Mining products
- 324 Petroleum products
- 3251, 3252,3253 Basic chemicals, resin, rubber, fertilizer

(4) Distribution & Delivery (logistics clusters; air cargo transfers, ground delivery)
- 421–429 Wholesale Trade
- 4 Truck Transportation Services
- 49 Warehousing + Mail & Package Delivery

(5) Visitor Services (may depend on regional, national or international air travel)
- 71 Tourism, recreation
- 72 Traveler Accommodations, Eating and Drinking

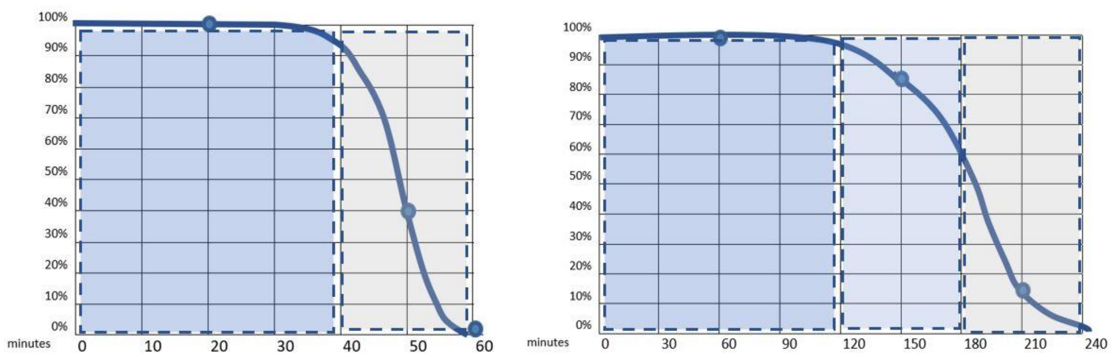
(6) Producer Services (office clusters, travel by air)
- 51 Info Tech
- 52 Finance
- 54 Professional and Scientific services
- 55 Management

(7) Consumer Services (retail clusters, depend on local area access)
- 44–45 Retail
- 811–814 Consumer Services
- 561 Business Support Services

Testing of Market Size Threshold Effects

One of the key aspects of both theory and business location research is the role of space/time "threshold" effects. Simply put, while businesses may cluster, they often draw workers from across a labor market or metropolitan area that is defined by a range of "reasonable" commuting times (43). The threshold is generally considered to be within a range of less than one hour and sometimes 40 minutes. This is supported by the fact that over 75% of US workers have a commute time over 15 minutes yet less than 23% have a commute longer than 40 minutes and less than 10% have a commute over 60 minutes (44). For our regressions, we explored use of travel time decay factors and threshold factors for defining local labor markets. We found that a composite of these factors, pivoting off the 40 minute and 60-minute thresholds, yielded the most consistent and highest significance findings for local access in our regressions. (See Figure 4A and regression results that follow.)

We also explored alternative definitions for same-day (passenger and freight delivery) markets. For truck deliveries, a practical threshold is roughly 3 hours (one way), which is consistent with an 8-hour worker shift with 6 hours of round trip driving and one hour at each end for loading and unloading freight. A similar type of planning time threshold is also applied for tourist day-trips. To account for the possibility of longer trips, we explored the use of alternative time decay factors and threshold factors within a 1 to 4-hour range. We found that a decay function with a sharp drop-off after 3 hours yielded the most consistent and highest significance findings for regional access in our regressions. (See Figure 4B and regression results that follow.)



(A) Local market: 100% of 0-40 minute range + 40% of 40-60 minute range

(B) Regional same-day market: 100% of 0-120 minute range + 85% of 120-180 minute range + 15% of 180-240 min. range

Figure 4. Values and Implied Curves Defining Local and Regional Market Thresholds

Cross-Sectional versus Time Series Analysis

The regressions are defined to predict variation in observed patterns of business clustering and wage rates among areas. There are two key reasons why this "cross-sectional" view is appropriate. First, prior studies have indicated that business siting location patterns evolve slowly over time as transportation networks change, so it often takes a decade or more for the effects of transportation access changes on business patterns to be fully observed (45, 46). As development of the U.S. highway network has matured, the cross-sectional view allows us to effectively observe the cumulative economic consequences of transportation access patterns that evolved over a long period of time, and compare how they differ among areas. We thus concentrate on how spatial differences in the economy relate to spatial differences in market access, without addressing the separate issue of the speed at which these variations evolve.

Second, while it is clearly valuable to also study how new changes in network access affect the subsequent evolution of industry clusters, there are currently no nationwide-level time series databases covering the types of access and types of areas addressed by this study. State Departments of Transportation (DOTs) have pooled funds to create the National Accessibility Evaluation, which compiles information on job markets and their changes over time for the 50 largest metro areas (47). However, it would take a much larger effort to extend this kind of data to also cover regional freight delivery and intermodal terminal access, and also extend the study to all other areas of the U.S. As the technology of transportation network modeling and geographic information systems is still evolving, such data will likely be developed in the future. For now, it is not surprising to find that the cross-sectional study approach is dominant in the published literature on connections between access, business location, and productivity (e.g., see [35–40]).

Dataset Characteristics

Table 3 summarizes the analysis dataset. It shows an extremely wide variation in economic patterns and access patterns across the U.S. The employment variable reflects the extent of zonal clustering. The zonal mean is far greater than the zonal median for each industry group, indicating that a relatively small fraction of zones accounts for a large share of the total. The wage variable shows significant variation among industries, with high-tech industries paying an average wage over triple that of visitor service industries. The intermodal access times are particularly notable as they show how some areas of the U.S. have very long travel times to access these gateways to national and international markets. Finally, it is notable that regional, same-day markets (e.g., access within 3 h each way) can be substantially larger than local markets (e.g., access within 1 h).

Table 3. Dataset Summary

Variable	Min.	Median	Mean	Max.
Dependent variable: employment				
High-tech/high-value mfg.	0	6	500	104,867
Misc. manufacturing	1	1,103	3,094	247,866
Bulk processing	0	974	2,567	212,454
Distribution	2	1,444	7,423	1,021,668
Visitor services	8	1,335	8,069	1,041,537
Producer services	6	1,332	10,459	1,294,716
Retail/consumer	7	3,855	20,294	2,195,186
Dependent variable: average wage				
High-tech/high-value mfg.	—	60,658	55,007	304,990
Misc. manufacturing	—	36,316	40,070	235,224
Bulk processing	—	38,890	42,263	204,958
Distribution	—	50,833	50,936	132,308
Visitor services	—	19,116	19,298	49,918
Producer services	—	37,083	40,370	207,798
Nearest intermodal terminals				
Airport activity (passenger boardings)	10,328	3,644,158	6,483,741	33,453,360
Airport activity (cargo pounds)	0	62,358,882	205,191,888	4,782,859,606
Marine port activity (tons)	788,939	5,813,777	21,795,454	275,512,500
Airport access time (minutes)	3	79	85	296
Marine port access time (minutes)	2	129	181	841
Intermodal rail access time (minutes)	2	112	133	667
Local market (population)				
Within 30 min	404	56,743	166,836	4,712,912
Within 40 min	404	117,003	303,435	7,651,211
Within 60 min	789	334,465	707,157	13,965,443
College educated %	1	19	21	79
Regional market (employment)				
Employment 0–60 min	869	492,782	900,193	13,121,713
Employment 60–120 min	5,842	837,964	1,203,997	14,084,620
Employment 120–180 min	12,481	1,973,584	2,622,288	27,978,777
Employment 180–240 min	22,457	2,965,768	3,644,283	33,793,970

Note: mfg. = manufacturing; Min. = minimum; Max. = maximum; Misc. = miscellaneous;
‘‘–”indicates no value because of miniscule or non-existent employment in that industry category.

Regression Analysis

Equations

We utilize a nonlinear regression with a natural log-log transformation, so regression coefficients represent elasticities. This makes it possible to ascertain how a given percent change in the explanatory variable leads to a corresponding percent change in the dependent variable (local employment or average wage for various industries). A second aspect of the nonlinear regression methodology is that it also includes exponents to capture nonlinear scale and travel time decay factors. In the case of airports and water ports, we also adopt a "gravity model" ratio formulation to capture both the positive effect of terminal size (a rough proxy for breadth of destinations) and the negative effect of access time. With the gravity model ratio, access time is not log transformed; this is discussed later under "alternative formulation." The gravity model formulation was not possible for intermodal freight rail facilities, as there were no publicly available size (freight volume) data.

The same explanatory factors are used for predicting both employment concentration and wage rates by industry, except that the employment regression has the intercept term suppressed to ensure that predicted employment approaches zero as population approaches zero.

For each industry (i) and zone (z)

$$
\begin{aligned}
\ln\,[\mathrm{EMP}_{(i,r)} = {} & \\
& \mathbf{B1}_{(i)} * \ln\,[\mathrm{LOCMKT}_{(z)}]^{\mathbf{C1}(i)} \\
& + \mathbf{D1}_{(i)} * \ln\,[\mathrm{REGMKT}_{(z)}] \\
& + \mathbf{E1}_{(i)} * \ln\,[\mathrm{A.SIZE}_{(z)}]/(\mathrm{A.TIME}_{(z)})^{\mathbf{F1}(i)} \\
& + \mathbf{G1}_{(i)} * \ln[\mathrm{P.SIZE}_{(z)}]/(\mathrm{P.TIME}_{(z)})^{\mathbf{H1}(i)} \\
& + \mathbf{I1}_{(i)} * \ln\,[\mathrm{R.TIME}]_{(z)} \\
& + \mathbf{J1}_{(i)} * \ln\,[\mathrm{EDUC}]_{(z)}
\end{aligned}
$$

$$
\begin{aligned}
\ln\,[\mathrm{WAGE}_{(i,r)} = {} & \mathbf{A2}_{(i)} \\
& + \mathbf{B2}_{(i)} * \ln\,[\mathrm{LOCMKT}_{(z)}]^{\mathbf{C2}(i)} \\
& + \mathbf{D2}_{(i)} * \ln\,[\mathrm{RGMKT}_{(z)}] \\
& + \mathbf{E2}_{(i)} * \ln\,[\mathrm{A.SIZE}_{(z)}]/(\mathrm{A.TIME}_{(z)})^{\mathbf{F2}(i)} \\
& + \mathbf{G2}_{(i)} * \ln[\mathrm{P.SIZE}_{(z)}]/(\mathrm{P.TIME}_{(z)})^{\mathbf{H2}(i)} \\
& + \mathbf{I2}_{(i)} * \ln\,[\mathrm{R.TIME}]_{(z)} \\
& + \mathbf{J2}_{(i)} * \ln\,[\mathrm{EDUC}]_{(z)}
\end{aligned}
$$

where:

$A_{(i)}, B_{(i)}, D_{(i)}, E_{(i)}, G_{(i)}, I_{(i)}, J_{(i)}$ are coefficients. They represent industry-specific impact elasticities since the equation is a log-log function.

$C_{(i)}, F_{(i)}, H_{(i)}$ are exponent factors that also vary by industry (i).

LOCMKT = local labor and consumer market size, a function of weighted average of the population within 0-60 minutes (note A)

REGMKT = relative size of regional non-local market, measured as ratio of [(weighted employment within 60-240 minutes) /(employment within 0-60 minutes)] (note B)

A.SIZE = annual passenger boardings or cargo pounds for the closest airport (notes C, D)

A.TIME = travel time to the closest airport (note C, E)

P.SIZE = annual cargo tonnage flows for the closest commercial cargo port notes C, D)

P.TIME = travel time to the closest commercial cargo port (notes C, E)

R.TIME = travel time to the closest truck-rail container loading facility (notes C, E)

EDUC = percent of population with a bachelor's degree

*(A) Local market is measured as population living within 0-40 minutes from the largest city in the county + 40% * population living within 40-60 minutes (weighting reflects a decay function)*

*(B) Regional market is a measured as employment within 60-120 minutes from the largest city in the county + 85% * employment within 120-180 minutes + 15% * employment within 180-240 minutes (weighting reflects a decay function). It is measured relative to 0-60 minute market to avoid correlation between local market and regional market size measures. Exception: for visitor services, regional market is based on population rather than employment.*

(C) The list of water ports and truck-rail container loading facilities is based on National Transportation Atlas Database (NTAD). Identification of airports is based on the FAA list of medium and large airports. Water ports are limited to the top 125 based on tonnage.

(D) Passenger volume is used for visitor services and producer services; container cargo tonnage is used for high value and misc. manufactured products, while bulk tonnage is used for bulk product industries. Volume represents a proxy measure for the likely breadth of destination options. No volume information was publicly available for intermodal rail terminals.

(E) Travel time is measured from the largest city in the county.

Results

Table 4 shows the regression results, including the statistically significant coefficients and the corresponding t-statistic (in parentheses). With the log-log functional form, coefficients are interpreted as elasticities, so in the case of local market access (B1), a 1% change in local market scale increases distribution employment by 0.25%. In the case of local markets, airports and water ports, there is also an exponential factor to capture further concentration of scale and time decay effects. The coefficients for all of the explanatory factors (with exponent effects) were found to be statistically significant for at least some industry groups. Exponential factors were not found to be increase the explanatory power for regional access and intermodal rail.

TABLE 4. Regression Results

"Coeff" represents coefficient value; "Exp" represents exponent factor; ( ) denotes t-statistic

REGRESSIONS	INTER-CEPT	LOCAL MARKET *(LOCMKT)*		REGIONAL MARKET *(REGMKT)*	AIRPORT *(ASIZE/ATIME)*		PORT *(PSIZE/PTIME)*		RAIL *(RTIME)*	EDUC *(EDUC)*	
(A) EMPLOYMENT	A1 Coeff.	B 1 Coeff.	C1 Exp.	D 1 Coeff.	E1 Coeff	F1 Exp.	G1 Coeff.	H1 exp.	I1 Coeff.	J1 Coeff	R^2
(1) High Tech/High Value	N.A.	0.0032 (12.14)**	2.50	n.s.	*1.669 (1.96)**	1.187	--	–	–	5.809 (12.52)**	0.43
(2) Misc. Manufacturing.	N.A.	0.713 (55.47)**	1.00	0.105 (3.87)**	–	–	0.075 (8.73)**	1.00	-0.226 (-7.77)**	–	0.37
(3) Bulk Processing	N.A.	0.618 (15.00)**	0.964	n.s.	–	–	0.160 (3.46)**	0.909	*see note*	–	0.36
(4) Distribution	N.A.	0.251 (12.51)**	1.330	0.0064 (4.22)**	1.306 (3.96)**	1.034	--	–	–	–	0.52
(5) Visitor Services	N.A.	0.178 (10.95)**	1.457	*0.003 (5.01)***	1.484 (4.40)**	0.996	--	–	–	–	0.51
(6) Producer Services	N.A.	0.154 (12.977)**	1.443	n.s.	1.407 (3.07)*	1.307	--	–	–	7.027 (35.18)**	0.69
(7) Retail/Consumer	N.A.	0.352 (17.58)**	1.267	n.s.	–	–	--	–	–	–	0.52
(B) WAGES	A2 Coeff.	B 2 Coeff.	C 2 Exp.	D 2 Coeff.	E2 Coeff.	F 2 Exp.	G2 Coeff.	H2 Exp.	I2 Coeff.	J2 Coeff.	R^2
(1) High Tech/ High Value	10.706 (258)**	0.0002 (10.75)**	2.934	n.s.	n.s.	1.941	--	–	–	0.564 (4.87)**	0.13
(2) Misc. Manufacturing.	7.379 (28.32)**	0.0412 (21.87)**	1.704	0.237 (1.864)*	–	–	n.s.	n.s.	n.s.	–	0.29
(3) Bulk Processing	9.566 (211)**	0.0002 (18.47)**	3.298	n.s.	–	–	0.0954 (4.08)**	0.910	*see note*	–	0.12
(4) Distribution	10.513 (588)**	0.000001 (13.25)**	4.736	n.s.	0.086 (6.29)**	0.672	--	–	–	–	0.13
(5) Visitor Services	9.535 (682)**	0.00003 (20.41)**	4.411	0.0006 (3.68)**	0.174 (7.90)**	1.081	--	–	–	–	0.18
(6) Producer Services	9.547 (260)**	0.0084 (17.60)**	1.722	n.s.	0.281 (7.64)**	1.179	--	–	–	1.357 (17.71)**	0.29
(7) Retail/Consumer	9.514 (589)**	0.00004 (26.55)**	3.691	n.s.	–	–	--	–	–	–	0.19

*** statistically significant at .99 confidence; * significant at.95 confidence*
n.s. indicates market access factor was tested but coefficient was not statistically significant,
-- *indicates intermodal explanatory factor was not tested for non-relevant modal option. (This also minimizes multicollinearity caused by spatial correlation of air, sea, and rail intermodal terminal location.)*
Note: Bulk product access to intermodal rail was not estimated due to unavailability of data. While rail is clearly important for bulk transport, the available dataset on rail intermodal terminals only covered TOFC/COFC (container) facilities which are not generally applicable for bulk transport.

Interpretation of Results Relative to Theory

The regression results show that the attraction of business activity (as reflected by employment concentrations) and associated productivity (as reflected by wage rates) are both greatest in locations with connectivity to markets, including local, regional, and intermodal (long-distance) markets. However, these effects differ significantly by industry. Key findings are noted below:

- *Local Market Access*—This variable is defined as the population accessible within a typical commuting range of the largest city in the area. As noted earlier, it is defined by a decay threshold over the 40–60 min range and serves as a proxy indicator of the size of local labor and shopper markets.

The positive coefficients across industries are in keeping with conventional expectations; it is logical that all types of economic activity increase with higher population. However, the exponent term in the employment equation is higher for high-tech, indicating notably increasing returns to scale for business attraction. This is consistent with research showing that larger labor markets increase the likelihood of finding workers with specific technological skills. The exponent term was higher in the wage equation than in the employment equation across all industries, indicating that higher wage effects are most evident in the larger job markets. Overall, the key takeaway for planners is that transportation links connecting residential communities and urban employment centers can enlarge local markets and thus grow economic activities that depend on population market size. It is also noteworthy that employment concentration and wage rates for high-tech and producer services are increased by having a more highly educated workforce.

- *Regional Market Access*—This variable captures the scale of economic activity (measured by total employment) that is outside of the local market but still accessible via a day trip to or from the largest city in the area. As noted earlier, regional market is defined by a decay threshold that pivots around a 3 h one-way travel time. This factor is expressed as a ratio of regional to local market size, to capture situations where there is a disproportionately large regional market relative to the local market size. This factor is shown to be relevant for the attraction of employment in manufacturing and distribution industries, and it is also a factor in manufacturing wage rates. For those industries, this variable serves as an indicator of the size of additional business supplier and buyer delivery markets that can be reached by same-day truck trips beyond the local market. The implication for planners is that transportation links that enlarge the connectivity of industrial sites to regional delivery markets can particularly support the growth of specialized supply chains and distribution centers.

- Visitor/recreation activities are a special case. Here we define the regional access ratio in relation to the population (rather than employment) as an indicator of the market for same-day personal travel. The finding is that employment and wages in this industry are increased by both the size of the same-day regional market and airport access. We are not able to capture the role of special (historical or geological) attractions, which are clearly also important.

- *Intermodal Gateways*—Airports serve as gateways to reach national and global markets. The variable is defined as a gravity model ratio in which the value increases with the size of activity occurring at the airport, and falls with increasing ground distance from the city. The statistical results confirm that producer services, high-value (high-tech) manufacturing, distribution, and visitor services all benefit from access to large airports for time-sensitive travel to reach long-distance markets. The interpretation is that these economic sectors depend on long-distance air travel for business relationships which may involve customers, incoming materials, or outgoing deliveries. The implication for planners is that transportation enhancement of air service can particularly support industries with national or global markets.

- Marine ports are also gateways connecting to global markets. The gravity model formulation (based on applicable tonnage/access time) confirms that production of both manufacturing and bulk products is associated with port connectivity, though the causation may be that the transportation investments follow rather than lead the location of those business activities.

- For intermodal rail, our dataset is limited to access time to container loading locations; the results show that proximity to these facilities is important for the location of manufacturing not classified as high-tech, though wage rates are not affected. Unfortunately, we were not able to obtain data on bulk intermodal rail facilities (which are often privately controlled).

Alternative Formulation

The preceding results reflect a formulation in which all variables are log transformed to reflect elasticities except for the gravity model decay functions representing access time to airports and water ports. We also tested an alternative regression specification in which we applied the log transformation to the entire size/time ratio. In all cases, the explanatory power of the regression (r-squared value) went down. Although the statistical significance level remained unchanged for coefficients in the employment equations, it fell to insignificance for almost half of the coefficients in the wage equations. There was a loss of statistical significance for the airport access effect on high-tech wages and the water port access effect on misc. manufacturing and bulk processing wages. There was also a loss of statistical significance for the local market size effect on bulk processing and visitor services, and the regional market size effect for misc. manufacturing and visitor services.

This result reflects that applying a log transformation to the entire ratio substantially compresses the effect of travel time differentials, reducing the scale of differences between short and long access times. So if wage effects are particularly localized around an airport or water port, those effects become harder to discern with the alternative specification. These findings suggest that further work is warranted to better distinguish the nonlinear effects of intermodal access on wages, and wage effects that are affected by both market size and intermodal terminal access.

Application of Results for Economic Analysis

The regression results can be of direct use for economic impact analysis and project prioritization, as they provide an econometric basis for calculating the potential for long-term economic development gains associated with proposed transportation system improvements that expand local, regional, or intermodal access. They can also be used to identify the specific industries and locations where employment and wage rate gains are likely to occur.

The regression results can also be applied in benefit/ cost analysis. Past studies have interpreted wage rate differentials as an indicator of productivity benefits that accrue from agglomeration externalities associated with greater market access (38, 48). In that respect, our wage rate regression findings can be used to calculate additional productivity gain accruing from market-scale economies associated with expanding regional markets and intermodal access. However, that will likely be an under-estimate of total productivity gain, as further productivity gains may also be reflected by (unobserved) increases in land costs, corporate profits, and retained earnings in addition to higher worker wages.

Conclusions

The empirical analysis shows how local population markets, regional business markets, and access to intermodal gateways play varying roles in affecting industry concentrations and wage rates. These impacts can potentially inform a broad spectrum of transportation investments in freight routes, passenger routes, and long-distance air and sea connections by public agencies and private operators. Outcomes can vary among sectors of the economy in ways that relate to their differing reliance on workforce, parts/materials suppliers, and buyer/user access. The distinctions between types of access, as shown here, can help enable more targeted project design, more insightful impact modeling and appraisal, and more comprehensive prioritization of proposed projects.

These findings indicate the importance of recognizing freight as well as passenger market access, and the need to also recognize regional and intermodal connectivity, as a part of benefit–cost assessments and prioritization decisions. Omission of these factors can be a source of modal and spatial bias in transportation investment and prioritization decisions.

This work can also be of value in planning processes, as it shows how one can incorporate considerations of regional and intermodal access to enable more strategic transportation investments that consider policy goals of equity, competitiveness, and economic development. These matters become increasingly important as interest grows in integrating transportation with broader investments to support workforce development, broadband development, and economic growth opportunities.

The findings of this study, with its focus on larger region effects, may also be seen as a complement to prior studies that focused on sub-metro area clustering. Together, the two types of study reinforce the two-stage aspect of location decisions for traded industries, with (a) an initial choice of site among labor markets, and (b) a subsequent choice of a specific site within the selected labor market. For instance, using the current dataset and its regression for producer services, we find that differences in local population market access (a proxy for labor market access) explains 58% of the variance in producer services employment among U.S. counties. That is far greater than the corresponding finding that differences in access to local population market explains just 17% of the variance in producer services employment among zones within a single metro area (38). In other words, labor market access is an important explanatory factor in explaining producer service employment among metro areas, but it becomes less of a factor for subsequent choices of location within a metro area.

Looking to the future, there are significant needs for further research to improve economic impact modeling and the assessment of wider economic benefits. Specifically:

- *Integration of spatial scales*—This study focuses on regional-scale market access and intermodal access effects, which are particularly important for manufacturing, distribution, and tourism activities. However, this study does not address local density and business proximity effects which have been addressed in prior studies focusing on smaller zones. This study also utilizes the concept of local and regional-scale thresholds for large area effects, in contrast to past studies that utilized more continuous gravity model decay functions. There is clearly a need to better integrate these differing spatial scales and perspectives.
- *Definition of access*—This study, like others covered in the literature review, examines access in relation to population and employment reachable within omnidirectional travel times. It does go further in relation to including directional connectivity to specific intermodal terminals. However, it is also possible to measure access by mode and in relation to linkages along and between corridors, or between locations that have complementary industries and resources. Such views can be particularly useful for assessing benefits of improving supply chain connectivity (e.g., between materials, parts producers, assemblers, and distributors) and knowledge links (e.g., enabling regional integration between specific cities and markets, and activities such as high-tech R&D satellite centers). There is clearly a need to advance spatial geography measures of clustering and access that recognize complementarities in corridor connections.
- *Time Dynamics*—This study derives findings from cross-sectional data. It would be beneficial to expand this kind of analysis to incorporate time series analysis that can examine changes occurring as transportation networks develop over time, and as the access needs of various industries change over time. This could also incorporate additional factors related to the industrial path dependency of areas, and variation in wage and employment effects among different types of industries and locations. It is also likely that spatial access relationships between residents, activity locations, and business supply chains will further evolve with emerging telework and e-commerce technologies.

References

1. Graham, D. *Wider Economic Benefits of Transport Improvements-Link Between Agglomeration and Productivity: Stage 1 Report*. UK Department for Transport, London, 2005.
2. Weisbrod, G. Models to Predict the Economic Development Impact of Transportation Projects: Historical Experience and New Applications. *Annals of Regional Science*, Vol. 42, 2008, pp. 519–543. https://doi.org/10.1007/s00168-007-0184-9.
3. Weisbrod, G. *Estimating Wider Economic Impacts in Transport Project Prioritisation Using Ex-Post Analysis*. OECD/ITF Discussion Paper 2016-3. OECD Publishing, Paris, 2016. https://doi.org/10.1787/444ad5c1-en.
4. Litman, T. *Introduction to Multi-Modal Transportation Planning: Principles and Practices*. Victoria Transport Policy Institute, Canada, 2021. https://www.vtpi.org/multimo-dal_planning.pdf.
5. Gambale, G. 34th Annual Corporate Survey and the 16th Annual Consultants Survey. Q1-2020. *Area Development*, 2020. https://www.areadevelopment.com/Corporate-Consultants-Survey-Results/Q1-2020/34th-annual-corpo rate-survey-16th-annual-consultants-survey.shtml.
6. Holl, A. Manufacturing Location and Impacts of Road Transport Infrastructure: Empirical Evidence From Spain. *Regional Science and Urban Economics*, Vol. 34, No. 3, 2004, pp. 341–363. https://doi.org/10.1016/S0166-0462(03) 00059-0.
7. Gibbons, S., T. Lyytika¨ inen, H. Overman, and R. Sanchis-Guarner. New Road Infrastructure: The Effects on Firms. *Journal of Urban Economics*, Vol. 110, 2019, pp. 35–50. https://doi.org/10.1016/j.jue.2019.01.002.
8. Wang, X., and R. Vom Hofe. *Research Methods in Urban and Regional Planning*, Springer, Berlin, Heidelberg, 2007. https://doi.org/10. 1007/978-3-540-49658-8_4. [AQ: 8]
9. Hoff, M., and R. Wall. Business Districts: The Spatial Characteristics of FDI Within Cities. *European Planning Studies*, Vol. 28, No. 2, 2020, pp. 273–295.
10. Kerr, W., and F. Robert-Nicoud. *Tech Clusters*. Working Paper 20-063. Harvard Business School, Boston, MA, 2020. https://www.hbs.edu/ris/Publication%20Files/20-063 _97e5ef89-c027-4e95-a462-21238104e0c8.pdf.
11. Zandiatashbar, A., and S. Hamidi. Transportation Amenities and High-Tech Firm Location: An Empirical Study of High-Tech Clusters. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. 2675: 820–831.
12. Weisbrod, G., D. Cutler, and C. Duncan. *The Role of Transit in Support of High Growth Business Clusters in the US*. American Public Transportation Association, 2013. https:// www.apta.com/wp-content/uploads/Resources/resources/ reportsandpublications/Documents/TransitHighGrowth ClustersUS-Final2013-1124-1.pdf
13. Hyunwoo, L., and J. C. Thill. Internodal Freight and Regional Accessibility in the United Staes. *Environment and Planning A: Economy and Space*, Vol. 40, No. 8, 2008, pp. 2006–2025. https://doi.org/10.1068/a38336.
14. Stein, N., A. Blair, and G. Weisbrod. *Freight Performance Measures: Measuring Freight Accessibility*. White Paper. Federal Highway Administration, US DOT, 2018. https:// www.ebp-us.com/sites/default/files/project/uploads/ EDRG_FreightAccessWhitePaper_18Sept2015-final.pdf.

15. Sonnenburg, F., and B. Braun. Impact of Airports on Spatial Patterns of Metropolitan Employment: The Case of Australia. *Erdkunde*, Vol. 71, No. 4, 2017, pp. 287–300. https://doi.org/10.3112/erdkunde.2017.04.02.

16. Sheard, N. Airport Size and Urban Growth. *Economica*, Vol. 86, No. 342, 2019, pp. 300–335. https://doi.org/10. 1111/ecca.12262.

17. Gibbons, S., and W. Wu. Airports, Access and Local Performance. *Journal of Economic Geography*, Vol. 20, No. 4, 2020, pp. 903–937. https://doi.org/10.1093/jeg/ lbz021

18. Klaassen, H., P. M. J. Warffemius, and A. I. J. M Van der Hoorn. Modeling the Clustering of Distribution Centers Around Amsterdam Airport Schiphol. *Journal of Airport Management*, Vol. 4, No. 3, 2011, pp. 265–279

19. Cambridge Systematics. *Economic Impact Study of Completing the Appalachian Development Highway System*. Appalachian Regional Commission, 2008. https://www. arc.gov/report/economic-impact-study-of-completing-the-appalachian-development-highway-system/.

20. van den Heuvel, F., L. Rivera, K. Van Donselaar, A. de Jong, Y. Sheffi, P. de Langen, and J. Franso. Relationship Between Freight Accessibility and Logistics Employment in US Counties. *Transportation Research Part A: Policy and Practice*, Vol. 59, No. 1, 2014, pp. 91–105. https://doi. org/10/10.1016/j.tra.2013.11.002.

21. Alstadt, B., G. Weisbrod, and D. Cutler. Relationship of Transportation Access and Connectivity to Local Economic Outcomes: Statistical Analysis. *Transportation Research Record: Journal of the Transportation Research Board*, 2012. 2297: 154–162.

22. Woodsma, C., and J. Jensen. Accessibility and Freight: Transportation and Land Use–Exploring Spatial-Temporal Dimensions. In *Access to Destination* (D. Levinson and Krizek, K., eds.), Emerald Group Publishing, Bingley, 2005, pp. 267–295. http://doi.org/10.1108/9780080460550-013.

23. Prologis. *The Evolution of Logistics Real Estate Clusters*. Supply Chain / Global, August, 2015. https://www.prolo-gis.com/logistics-industry-research/evolution-logistics-real-estate-clusters

24. Miller, C., B. Richard, M. Sarder, T. Sulbaran, and M. Lipinski. *Job Creation Factors for Inland and Near Dock Intermodal Facilities*. University of Memphis, 2013. https://www.memphis.edu/ifti/pdfs/research_job_creation_ factors.pdf.

25. Notteboom, T., and J. Rodrigue. Inland Terminals Within North American and European Supply Chains. *Transport and Communications Bulletin for Asia and the Pacific*, Vol. 78, No. 1, 2009, pp. 1–39.

26. Sheffi, Y. *Logistics Clusters*. MIT Press, Cambridge, MA, 2012.

27. Karayel, S. Power of Automotive Supplier Cluster: The Case of BMW in South Carolina. *European Scientific Journal*, Vol. 13, No. 4, 2017, p. 87. https://doi.org/10.19044/ esj.2017.v13n4p87.

28. Colucci, J. *Strengths, Uniqueness and Synergies Across the Southeast, Manufacturing Innovation Blog*. National Institute of Standards and Technology (NIST), 2017. https:// www.nist.gov/blogs/manufacturing-innovation-blog/ strengths-uniqueness-and-synergies-across-southeast.

29. Schultz, B. The Rise of the Southern Automobile Industry. *City Data*, 2016. https://www.city-data.com/blog/619-rise-southern-automobile-industry/#ixzz7DM89ZDy3.

30. Hesse, M., and J. Rodrigue. The Transport Geography of Logistics and Freight Distribution. *Journal of Transport Geography*, Vol. 12, No. 3, 2004, pp. 171–184. https://doi. org/10.1016/j.jtrangeo.2003.12.004.

31. Dablanc, L., S. Ogilvie, and A. Goodchild. Logistics Sprawl: Differential Warehousing Development Patterns. *Transportation Research Record: Journal of the Transportation Research Board*, 2014. 2410: 105–112.

32. Zajac, G. The Role of Air Transport in the Development of International Tourism. *Journal of International Trade, Logistics and Law*, Vol. 2, No. 1, 2016, pp. 1–8. http://jital.org/index.php/jital/article/view/37.

33. Dimitriou, D. Comparative Evaluation of Airports Productivity Towards Tourism Development. *Cogent Business and Management*, Vol. 5, No. 1, 2018, p. 1464378. https://doi.org/10.1080/23311975.2018.1464378.

34. Doerr, L., F. Dorn, S. Gaebler, and N. Potrafke. How New Airport Infrastructure Promotes Tourism: Evidence From a Synthetic Control Approach in German Regions. *Regional Studies*, Vol. 54, No. 10, 2020, pp. 1402–1412. https://doi.org/10.1080/00343404.2020.1714022.

35. Ciccone, A., and R. Hall. Productivity and the Density of Economic Activity. *American Economic Review*, Vol. 86, No. 1, 1996, pp. 54–70. https://www.jstor.org/stable/211 8255.

36. Fujita, M., P. Krugman, and A. Venables. *The Spatial Economy: Cities, Regions, and International Trade*. MIT Press, Cambridge, MA, 1999.

37. Graham, D. Agglomeration, Productivity and Transport Investment. *Journal of Transport Economics and Policy*, Vol. 41, No. 3, 2007, pp. 317–343. http://www.jstor.org/ stable/20054024.

38. Graham, D., and S. Gibbons. Quantifying Wider Economic Impacts of Agglomeration for Transport Appraisal: Existing Evidence and Future Directions. *Economics of Transportation*, Vol. 19, 2019, p. 100121. https://doi.org/ 10.1016/j.ecotra.2019.100121

39. Weisbrod, G., J. Goldberg, and P. Frank. Measuring the Regional Economic Impact of Transportation Access Improvements in the Context of a Large Metropolitan Region. *Transportation Research Record: Journal of the Transportation Research Board*, 2021. 2675: 417–427.

40. Graham, D., P. Melo, P. Jiwattanakulpaisarn, and R. Noland. Testing for Causality Between Productivity and Agglomeration Economies. *Journal of Regional Science*, Vol. 50, No. 5, 2010, pp. 935–951. https://doi.org/10.1111/ j.1467-9787.2010.00676.x.

41. Weisbrod, G., N. Stein, C. Williges, P. Mackie, J. Laird, D. Johnson, D. Simmonds, E. Ogard, D. Gillen, and D. Vickerman. *Assessing Productivity Impacts of Transportation Investments*. NCHRP Report 786. Transportation Research Board, Washington, D.C., 2014. https://doi.org/10.17226/22294.

42. Implan. *Comparison of IMPLAN Source Data for Employment and Labor Income*. 2020. https://implanhelp.zendesk. com/hc/en-us/articles/115009505747-Comparison-of-IMPLAN-Source-Data-for-Employment-and-Labor-Income.

43. US Bureau of Labor Statistics. *What are Labor Market Areas?*Local Area Unemployment Statistics, 2021. https:// www.bls.gov/lau/laufaq.htm#Q06.

44. Burd, C., M. Burrows, and B. McKenzie. *Travel Time to Work in the United States: 2019*. ACS-47. American Community Survey Reports, 2021. https://www.census.gov/con tent/dam/Census/library/publications/2021/acs/acs-47.pdf.

45. Lynch, T. Chapter 3, Twin Counties Study Update. In Economic Development Research Group: *Sources of Regional Growth in Non-Metro Appalachia: Vol. 3 Statistical Studies of Spatial Economic Relationships*, Appalachian Regional Commission, 2007, pp. 28–44. https://www.arc.gov/wp-content/uploads/2020/06/source sofgrowth_vol1through4_full.pdf.

46. Economic Development Research Group. *Interactions Between Transportation Capacity, Economic Systems, and Land Use*. Strategic Highway Research Program, Transportation Research Board, Washington, D.C., 2012. https://nap.nationalacademies.org/login.php?record_id= 22085.

47. University of Minnesota. *National Accessibility Evaluation Pooled-Fund Study*. Minnesota Department of Transportation, 2022. https://access.umn.edu/research/pooledfund/documents/2022NAE_pooled_fund_fact_sheet.pdf.

48. de Groot, H., J. Poot, and M. Smit. *Agglomeration, Innovation and Regional Development: Theoretical Perspectives and Meta-Analysis*. Discussion Paper 07-079/3. Tinbergen Institute, Amsterdam, Netherlands, 2007. http://dx.doi. org/10.2139/ssrn.1021942.