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Abstract

This paper analyzes the relationship between freight accessibility and logistics employment in the US. It develops an accessibility measure relevant for logistics companies based on a gravity model. This allows to analyze accessibility of US counties focusing on four different modes of transportation: road, rail, air, and maritime. Using a Partial Least Squares model, these four different freight accessibility measures are combined into two constructs, continental and intercontinental freight accessibility, and related to logistics employment, differentiating counties inside metropolitan areas from those outside. Results show that highly accessible non-metropolitan counties attract more logistics employment than other non-metropolitan counties. In metropolitan counties, no significant relationship was found between freight accessibility and logistics employment. This is primarily explained by the highly significant relations of both freight accessibility and logistics employment with county population.

Keywords: Accessibility, Freight transport, Logistics employment

1. Introduction

One of the key factors to a region's economic performance is a reliable and efficient transportation infrastructure. *"A well-developed transportation system provides adequate access to the region, which in turn is a necessary condition for the efficient operation of the manufacturing, retail, labor, and housing markets"* (Ozbay et al., 2006, p. 3). The accessibility of a location is, naturally, an important factor for the location decision of logistics companies (such as third party logistics service providers, warehouses, motor carriers, and the logistics/distribution operations of retailers, distributors and manufacturers). Better accessibility results in lower transportation costs and a shorter time to the market (Limão and Venables, 2001), which have a direct impact on the cost and service level that logistics operations enjoy. Therefore, logistics employment is

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expected to be concentrated in areas that are highly accessible. Hence, it is not surprising that improvements to the road network significantly affect the location of agglomerations of logistics firms (Taniguchi et al., 1999), that logistics clusters in the US are primarily developed close to major airports and seaports and in central areas such as Chicago, Kansas City and Dallas (Rivera and Sheffi, 2012), or that logistics establishments in the Netherlands relocate relatively often in areas with intermodal terminals (Van den Heuvel et al., 2013). In this paper, we analyze whether there is a general relation between freight accessibility and logistics employment.

Several studies on the relation between accessibility and employment have found that accessibility is an important factor for urbanization (population and employment growth, see e.g. Jiwattanakulpaisarn et al. (2010) and Song et al. (2012)). However, the specific relationship between freight accessibility and logistics employment has hardly been studied before. This paper addresses this gap in the literature.

An analysis of the impact of accessibility on logistics employment requires a freight accessibility measure. Although freight accessibility is important for location decisions of companies (Porter and Rivkin, 2012), limited efforts have been put in developing freight accessibility measures, in contrast with passenger accessibility. This may be explained by the fact that especially passenger cars dominate road usage. Passenger cars account for 91.8% of the vehicle-miles on US roads, while trucks only account for 7.4% of the vehicle-miles traveled[1] (US Department of Transportation, 2004).

The remainder of this paper is structured as follows. Section 2 presents an overview of the relevant literature on the relationship between accessibility and employment, while section 3 reviews the academic literature on accessibility measures. Section 4 presents an accessibility measure especially developed for freight transport. Using data at the county level in the US, section 5 presents the analysis into the relation between freight accessibility and logistics employment per county, based on a Partial Least Squares model. Finally section 6 concludes the paper and discusses options for further research.

2. Relationship between freight accessibility and logistics employment

"The more accessible an area is to the various activities in a community, the greater its growth potential" (Hansen, 1959, p. 1). Several studies found a relation between accessibility and growth. Thompson and Taniguchi (2001) argue that the construction of transportation infrastructure (increasing accessibility) leads to employment growth and lower consumer prices of commodities. Weisbrod et al. (1993) found that the impact of airport-induced job growth on land use in the vicinity of airports is substantial. Areas within four miles of airports added jobs two to five times

[1]The rest are mainly other buses and motorcycles that represent 0.6%.

faster than the overall suburban ring in which the airport is located. Most of the employment was concentrated around the airport or along a major access corridor within fifteen minutes of the airport. Jiwattanakulpaisarn et al. (2010) found that increased accessibility is a determinant of state employment growth in the services sector. Song et al. (2012) found that accessibility is closely linked to industrial agglomerations in the Seoul metropolitan area. In addition, several authors have analyzed the effect of accessibility on labor supply (see e.g. Hansen, 1959; Banister and Berechman, 2000; Berechman and Paaswell, 2001; Ozbay et al., 2006; Du and Mulley, 2007). A common approach is to assume that individuals allocate their total daily hours between work and non work activities. Hence, reduced travel time will result in more time available for both work and leisure time activities. Given assumptions on work/leisure time substitution as well as on the income effect from reduced travel times and costs, improved accessibility has a positive effect on the amount of labor that individuals are willing to supply (Ozbay et al., 2006).

This study expands Bowen's (2008) study, in which he correlated the number and growth of warehouse establishments per US county to accessibility. Based on an analysis in 143 counties which were part of 50 randomly selected metropolitan statistical areas, Bowen (2008) found a high correlation between the number of warehouse establishments in a county and the county's air and highway accessibility, in 1998 and 2005. He also found a high correlation between these accessibility measures and the growth in the number of warehouse establishments in the period 1998-2005.

Hesse (2008) argues that because of the need for inexpensive space and extraordinary transportation accessibility by logistics operations, logistics investments may work as precursors in economic development of areas. This argument is also advanced by Sheffi (2012), who demonstrates that logistics clusters attract manufacturing sub-clusters.

However, none of the aforementioned works analyzes specifically the relationship between freight accessibility and logistics employment. In the logistics industry high accessibility is a desirable condition for a firm's location, because it represents lower transportation costs and shorter time to markets (Limão and Venables, 2001). Hence, areas with better accessibility are expected to attract logistics firms, increasing the associated logistics employment. This paper investigates the hypothesis that areas with higher accessibility have higher levels of logistics employment.

3. Accessibility measures

Several authors developed accessibility measures (Ingram, 1971; Morris et al., 1978; Handy and Niemeier, 1997; Thomas et al., 2003; El-Geneidy and Levinson, 2006; Bowen, 2008). Most are specifically developed for passenger transport. Only a few authors explicitly analyzed freight accessibility. Thomas et al. (2003) analyze freight accessibility in Belgium based on three different transportation modes: road, rail, and waterways. These authors use gravity-based measures weighting the nodes of the transportation system by population and economic activity. They conclude that there is a positive relation between the transportation infrastructure and population, but economic activities are less associated with the transportation system than with the population.

To analyze the relationship between accessibility and the number of warehouse establishments, Bowen (2008) defined four different accessibility measures, based on different modes of transportation. Air accessibility was measured by an ordinal value based on the distance to the nearest airport and the air-cargo tonnage handled at that airport. Similarly, maritime accessibility is measured with an ordinal value on indices based on the distance to the nearest container port and the number of containers handled at that port. Road and rail accessibility are measured with density-based measures. Road accessibility is defined as the total centerline length of the interstate and other elements of the national highway system within a county divided by the county's area. Similarly, rail accessibility is defined as the length of all Class I railroads within a county divided by the county's area.

This paper extends and improves this analysis. Like Bowen, we define accessibility measures based on four different modes of transportation. However, although Bowen's measures are relatively easy to calculate, they suffer from a major shortcoming: The density-based measures calculate accessibility values per county independent of the accessibility of adjacent counties. However, (freight) accessibility is also determined by (rail)roads in adjacent counties. Adjacent countries are taken into account in the gravity-based accessibility measures (see e.g. Handy and Niemeier, 1997; Thomas et al., 2003; El-Geneidy and Levinson, 2006) used in this paper to define freight accessibility with four different transport modes). These measures are based on the following definition of accessibility (Hansen, 1959, p. 73) *"accessibility at point 1 to a particular type of activity at area 2 ... is directly proportional to the size of the activity at area 2 ... and inversely proportional to some function of the distance separating point 1 from area 2. The total accessibility* [to the type of activity of interest] *at point 1 is the summation of the accessibility to each of the individual areas around point 1"*. Gravity-based measures weigh opportunities, usually the quantity of an activity in a certain area, by impedance, generally a function of distance, travel time, or travel costs.

Accessibility measures based on gravity models are a generalization of cumulative opportunity and random utility measures, two other commonly used accessibility measures (Handy and Niemeier, 1997; Páez et al., 2012). Cumulative opportunity measures count the number of opportunities that can be reached within a predetermined travel time or distance. Gravity-based measures can be formulated as cumulative opportunity measures with the impedance function equal to one if within the predetermined distance/time and zero otherwise (Koenig, 1980; Handy and Niemeier, 1997). The major disadvantage of the cumulative opportunity measures is the arbitrary cut-off value used for the predetermined travel time or distance. For example, if the airports within 70 kilometers are counted, an airport at 68 kilometers is taken into account, while an airport at 72 kilometers is not.

Random utility measures use preferences of individual travelers to estimate the utility of certain choices (for example, mode choice in travel to work). A metric that takes into account the contribution of all such utilities for a set of individuals in a location is used as an accessibility measure. A common example is the multinomial logit model which uses a maximum likelihood estimator to calculate the parameter of the utility of each alternative, given data about the attributes of that and competing alternatives. The denominator of the multinomial logit model can be used as an accessibility measure, since it is a scalar summary of the expected utility of a set of travel alternatives (Ben-Akiva and Lerman, 1985). These measures were originally developed to model individuals' travel choices and reflect the individual's attributes. Utility-based measures use observable temporal and spatial transportation components of specific choices in person-specific choice sets (Handy and Niemeier, 1997). In the case of freight transport, these person (in this case company) specific choices can be approximated by a function of activity and distance. The result again is a gravity-based metric with an exponential functional form.

4. Freight accessibility measures for logistics establishments in the US

This section describes the accessibility measures in detail. For comparison, AppendixA presents the measures used by Bowen (2008). The modes of transport that are included are road, air, maritime, and rail transport.

4.1. Gravity-based accessibility measures

As described in section 3, gravity-based measures use the distance or travel time to other areas and the activity in these other areas to measure accessibility. We use the following standardized measure $A_{g,i}$ for all US counties $i \in \{1, \dots I\}$:

$$A_{g,i} = \frac{a_{g,i}}{\frac{1}{I}\sum_{j \in I} a_{g,j}}$$

$$a_{g,i} = \sum_{j \in I} w_j \cdot f(t_{i,j})$$

with: $A_{g,i}$ = Accessibility (gravity-based) of county i, w_j = Weight representing the importance of location j, $t_{i,j}$ = Measure of separation between counties i and j (generally being distance or time), $f(t_{i,j})$ = Impedance function, I = Number of US counties (= 3109).

Gravity-based measures explicitly take into account that accessibility not only is the ease with which other areas can be reached, but also the importance of these areas. This is determined by the weight w_j. With various ways of measuring the importance of locations and of determining the separation (impedance) between counties, several gravity-based measures for freight accessibility are defined.

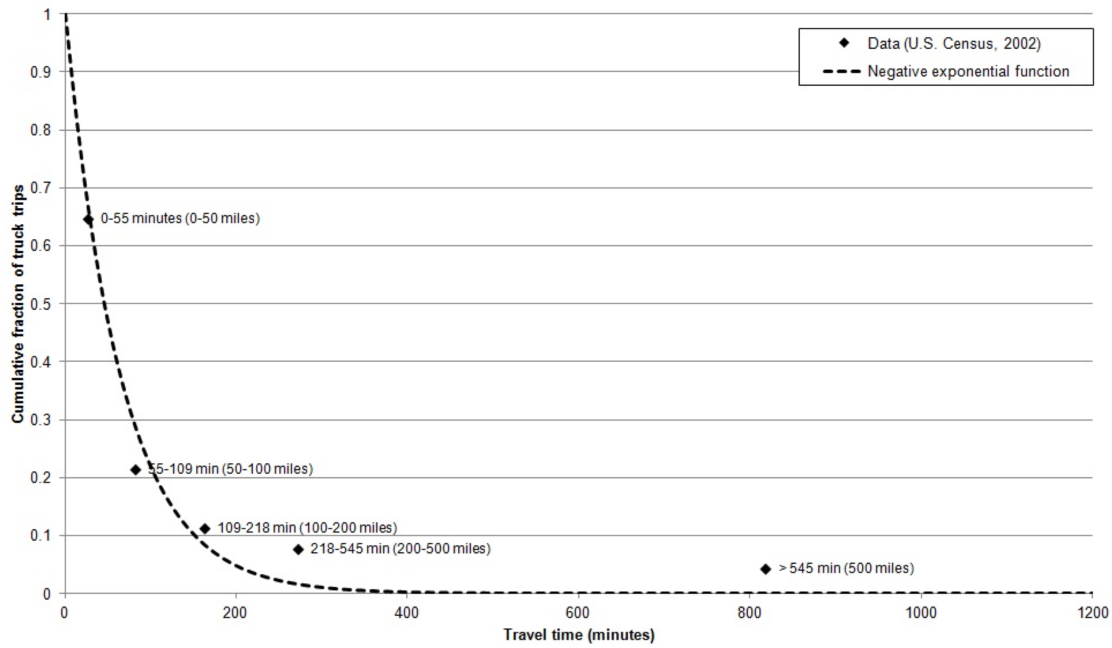

Figure 1: Impedance function used, based on primary range of operations of US trucks (US Census, 2002) and an average speed of 55 miles per hour

4.2. Road accessibility

For the road accessibility measure, $t_{i,j}$ is defined as the travel time in minutes between the center points of counties i and j.[2] The following impedance function is used:

$$f(t_{i,j}) = \begin{cases} 1 & \text{if } i = j \\ b \cdot e^{-ct_{i,j}} & \text{if } i \neq j \text{ and } t_{i,j} \leq t_{max} \\ 0 & \text{otherwise} \end{cases}$$

with $t_{max} = 720$ (see below), $b = 1.0000$ and $c = 0.0166$.

The impedance function is based on data describing the primary range of operations of US trucks (US Census, 2002). As these data present the number of truck trips for five different range classes, these indicate what weight should be given to activities within a certain travel time. A negative exponential function fits these data best. Figure 1 presents the function used in this paper.[3] Because $f(t_{i,j})$ approaches zero as $t_{i,j}$ increases, a maximum t_{max} is used, obviating the need for a complete matrix of travel times between all 3109 US counties.

[2]These travel times were determined using the US detailed streets map from Tele Atlas North America 2007, available from ESRI (www.esri.com, accessed December 2012).

[3]Parameters were determined by fitting the best function on the data, with CurveExpert Professional 1.3 (www.curveexpert.net, accessed December 2012). This software uses the Levenberg-Marquardt method to solve nonlinear regressions, which combines the steepest-descent method and a Taylor series based method (Levenberg, 1944; Marquardt, 1963).

The importance of county j determines how much weight it gets in determining the accessibility of county i. To measure road accessibility per county, importance is measured in two different ways:

- A_g(*road:distribution*) uses retail sales (US Census, 2007a) in county j, as many logistics companies focus on distribution to retail outlets.
- A_g(*road:manufacturing*) uses the value of shipments of all manufacturing establishments (US Census, 2007a) in county j. This represents locations were raw material and parts are transported to. For these data, the US Census does not disclose about 15 percent of the county values, only omitting the counties where manufacturing employment is less than 500 people.

4.3. Air, maritime, and rail accessibility

Similar to road accessibility, air, maritime, and rail accessibility of US counties can be measured using the travel times between counties by air, sea, and rail, respectively. However, while road travel times can be calculated relatively easily, this is not the case for travel times using other transport modes. These times depend on the services provided on these networks. The road network can be accessed by everybody with a motor vehicle on every moment of the day. The air, maritime, and rail transport networks can only be accessed at specific locations at specific moments in time, determined by the services provided by the operators on these networks. Consequently, air, maritime, and rail accessibility are measured based on the travel times by road needed to access these networks, i.e. $t_{i,j}$ is the travel time by road from the center point of county i to the center point of county j, that has an airport, seaport, or rail terminal.

Air accessibility is defined as $A_g(air)$. The size of the (air)port, measured by the cargo handled, is used as a proxy for the connectivity or importance of the (air)port. Hence, the weight w_j is defined based on the total landed weight of the top 25 US freight airports, which is the certificated maximum gross landed weight of the aircraft as specified by the aircraft manufacturers in county j (US Department of Transportation, 2010). These airports account for about 75% of the landed weight of all US freight airports.[4] Similarly, maritime accessibility is defined as $A_g(maritime)$. The total loaded container traffic (in TEU) of the top 25 US seaports (US Army Corps of Engineers, 2010) in county j is used to approach the importance of the seaport in that county (w_j). These top 25 ports account for about 98% of the loaded container traffic of all US seaports.

While many operators provide air and maritime transportation services, the freight rail network

[4] Analyses were also conducted on the top 30 and top 35 US freight airports, accounting for 79% and 81%, respectively, of the landed weight of all 124 US freight airports. Results were similar to the ones presented for the top 25 US freight airports.

in the US is mainly operated by seven Class I freight railroad companies.[5] Data about the cargo handled at the terminals are not available. Hence, rail accessibility, $A_g(rail)$, uses the number of intermodal rail terminals from different Class I freight railroads (US Department of Transportation, 2011b) in county j as a proxy for the size of activity or importance of the rail hubs in the county (w_j). The importance of the area is higher the higher the number of railroad companies that have an intermodal terminal located in the area, as shippers can reach more locations by rail and have more bargaining power.

5. Accessibility of US counties and the relation to logistics

This section applies the accessibility measures described above on a county level in the US and relates this to the logistics employment per county.

5.1. Material used

Logistics employment is defined as the paid employees of the establishments performing activities in the following sectors: freight transport, cargo handling, storage and warehousing, and other supporting transport activities. AppendixB presents a list of NAICS codes used to identify logistics establishments. We use logistics employment instead of logistics establishments, as this better approximates the size of the logistics sector per region and hence, the need for good accessibility.

Data are gathered from the 2007 County Business Patterns (US Census, 2007a,b). All data used are from 2007, as these are the most recent US Census Economic Survey data available. Since data are gathered on a six-digit NAICS code level, not all employment data are disclosed by the US Census. In the data, 29% of the counties do not have logistics employment, even though there are logistics establishments. Hence, in counties where data are not disclosed, logistics employment was estimated based on the number of establishments within a particular employment class and the average size of a logistics establishment in that class. Based on these estimates, the average logistics employment per county equals 1029 people (with a median of 149) and the average number of logistic establishments per county is 58 (with a median of 21). Figure 2 depicts the logistics employment per county.

Previous studies have shown that there is a significant relation between the accessibility and population of a region (Thomas et al., 2003; Zhenbo et al., 2011; Chi, 2012; Fan et al., 2012). In addition, population is strongly related to employment (De Graaff et al., 2012a). This also

[5] Railroad class is determined based on revenue, with "Class I" implying the largest revenue (at least $400 million annually in 2010). The five US Class I freight railroads include the Burlington Northern and Sante Fe (BNSF), CSX Transportation (CSX), Kansas City Southern (KCS), Norfolk Southern (NS), and Union Pacific (UP). The two large Class I Canadian Railroads, Canadian National (CN) and Canadian Pacific (CP), operate both in the US and Canada.

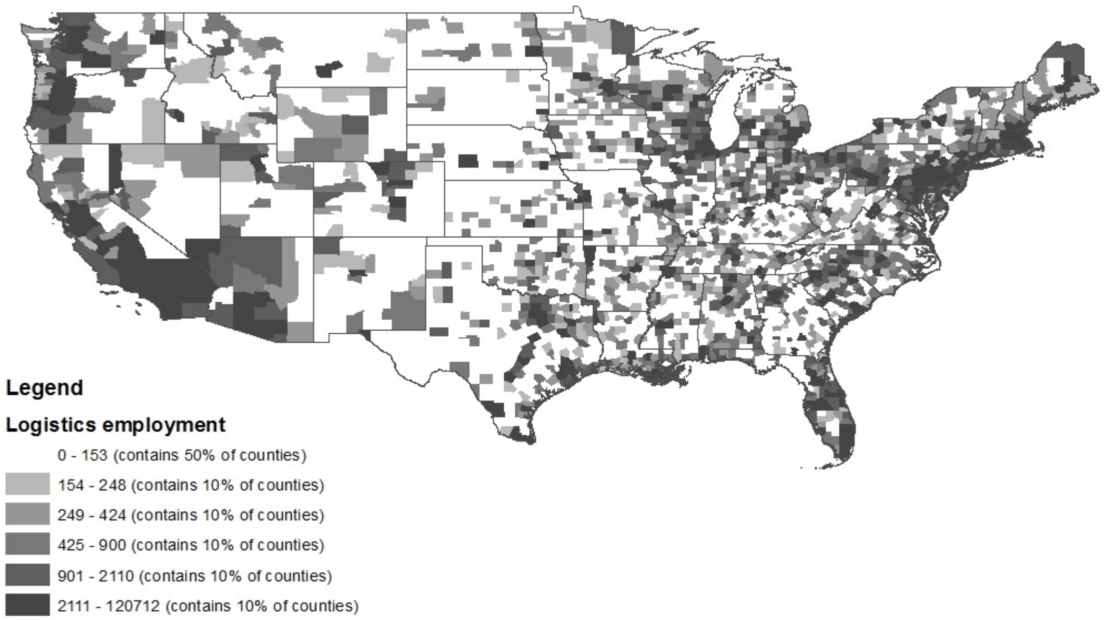

Figure 2: Top 50% counties based on logistics employment

applies to the distribution sector (De Graaff et al., 2012b). Populated centers offer availability of labor and proximity to consumers for logistics companies. Hence, we include this variable in the analysis. The population of adjacent counties is considered as well, as Jiwattanakulpaisarn et al. (2010) showed that employment gains from improvements in interstate highways may negatively affect employment in other states due to negative spillovers, thus shifting service jobs away from other states. This effect may also be relevant on a country-level.

The 3109 counties in the US are rather diverse. The average population per county is 96,372 people, while the median is 25,605. Based on these differences between the US counties, the analyses are performed separately on counties in metropolitan statistical areas (1,088 counties) and counties not in these areas (2,021 counties). Metropolitan statistical areas are geographic entities defined by the Office of Management and Budget (OMB) for use by Federal statistical agencies. A metropolitan area contains a core urban area of 50,000 or more people. Each metropolitan area consists of one or more counties and includes the core urban area, as well as any adjacent counties that have a high degree of social and economic integration with the urban core (measured by commuting to work, see US Census, 2012b). Table 1 presents descriptive statistics of the two sets of counties.

Table 2 shows the correlations between the accessibility measures described in section 3 and the logistics employment per US county. All accessibility measures have a significant relation with logistics employment. In addition, population has a very high correlation with logistics employment, especially in the metropolitan area counties, and also a significant correlation with

Table 1: Descriptive statistics of US counties

		Population (#)	Logistics employment (#)
Total	Sum	299,620,766	3,199,866
	Median	25,605	149
	Average	96,372	1,029
	St. Dev.	309,917	3,951
Metropolitan	Sum	250,519,926	2,725,681
	Median	96,508	755
	Average	230,257	2,505
	St. Dev.	495,954	6,398
Non-metropolitan	Sum	49,100,840	474,185
	Median	16,598	89
	Average	24,295	235
	St. Dev.	23,835	437

all accessibility measures. While Bowen (2008) only uses correlations to conclude that there is a relation between the number of warehouse establishments and accessibility per county, table 2 shows that in most cases the correlation between accessibility and population is higher than the correlation between accessibility and logistics employment. Hence, to test whether the relationship between logistics employment and freight accessibility is not spurious, other techniques have to be used that are able to control for the effect of population. This will be done in the next section.

5.2. Methodology

In order to test whether accessibility is a good predictor of logistics employment per county while population is controlled for, a variance based structural equation modeling approach known as PLS path modeling is used. While covariance based structural equation modeling approaches (e.g., LISREL) use maximum likelihood estimation, aiming to maximize the likelihood that the model equals the original correlation matrix, PLS can be considered as a multivariate extension of ordinary least squares (OLS) regression. In fact, the iterative algorithm performed in PLS

Table 2: Pearson correlation coefficients. Correlation coefficients for metropolitan area counties (N = 1088) are shown above the diagonal and correlation coefficients for non-metropolitan area counties are shown below the diagonal (N = 2021).

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Logistics employment		0.904*	0.392*	0.401*	0.447*	0.347*	0.540*	0.413*
(2)	Population	0.565*		0.491*	0.487*	0.471*	0.299*	0.621*	0.385*
(3)	Population in adjacent counties	0.161*	0.388*		0.537*	0.488*	0.265*	0.392*	0.369*
(4)	$A_g(road{:}distribution)$	0.360*	0.526*	0.347*		0.806*	0.476*	0.640*	0.607*
(5)	$A_g(road{:}manufacturing)$	0.337*	0.447*	0.263*	0.883*		0.447*	0.446*	0.679*
(6)	$A_g(air)$	0.096*	0.079*	0.030	0.306*	0.340*		0.363*	0.450*
(7)	$A_g(maritime)$	0.086*	0.202*	0.166*	0.320*	0.144*	-0.027		0.297*
(8)	$A_g(rail)$	0.305*	0.391*	0.227*	0.758*	0.771*	0.494*	0.209*	

* Significant with $\alpha < 0.05$.

generally consists of a series of OLS analyses (Chin, 1998). As a result PLS does not make assumptions about the underlying distributions (Fornell and Bookstein, 1982; Chin, 1998; Hair et al., 2011), while covariance based structural equation modeling approaches assume multivariate normality and independence between observations. Hence, PLS is a less demanding method when it comes to the measurement level of the variables, sample sizes, and distributional assumptions (Chin, 1998). In addition, while covariance based structural equation modeling approaches are especially well suited for studies comprising behavioral analyses, PLS can also be used with other types of empirical data and if the primary research objective is the maximization of explained variance in the endogenous constructs (i.e., prediction) instead of achieving model fit.

PLS allows for the configuration of formative measurement models. Contrary to reflective measurement models, formative measurement models can best be used when the items describe and define the construct rather than vice versa (Petter et al., 2007). To measure freight accessibility per US county, we use formative measures that take into account all modes of transport, consistent with the decision rules by Jarvis et al. (2003). We distinguish between intercontinental freight accessibility and continental freight accessibility. While (rail)roads are mainly used to travel within the US (or to adjacent countries, like Canada), (air)ports are also used to travel overseas. Hence, intercontinental and continental accessibility are modeled separately with two constructs. The use of a formative measurement model has methodological implications. The concepts of internal consistency, reliability, and convergent validity are not meaningful if formative indicators are involved (Hair et al., 2011); formative indicators are primarily based on a theoretical rationale.

Compared to ordinary least squares regression, PLS has two advantages relevant for our analysis. The most important one is that a single OLS model is not very appropriate to estimate a causal chain of relationships; OLS only analyzes relationships between (multiple) independent variables and one dependent variable. In contrast, PLS models can capture logical flow among the variables of our model. Therefore, independent and dependent variables are usually referred to as exogenous and endogenous variables, respectively, in PLS models (Chin, 1998). In our analyses, not only the relationship between freight accessibility and logistics employment is relevant, but so is the relation between population and freight accessibility. Another advantage of PLS models is that different variables can be combined to constitute one (multi-item) construct. In this paper, accessibility measured by different modes of transport can be combined to form two freight accessibility constructs, while ordinary least squares regression does not allow for this.

Figure 3 presents the model that is used to test for a relationship between freight accessibility and logistics employment. The model contains five different constructs. Logistics employment, population, and population of adjacent counties are measured with only one variable per construct. Freight accessibility is split up into two constructs, namely intercontinental and continental freight accessibility. $A_g(\textit{road:manufacturing})$ and $A_g(\textit{rail})$ define continental freight accessibility,

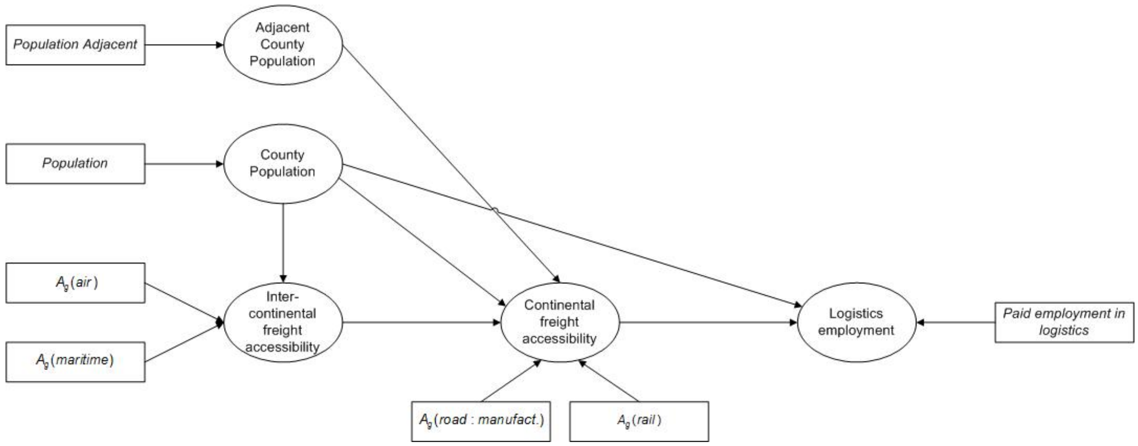

Figure 3: Measurement and structural model with gravity-based accessibility measures

as these modes of transportation are primarily used to travel within the continent. $A_g(maritime)$ and $A_g(air)$ define intercontinental freight accessibility. Intercontinental freight accessibility has a relation with logistics employment via continental freight accessibility, as the development of (rail)roads is also influenced by the locations of (air)ports. Furthermore, A_g(*road:distribution*) was left out of the model, due to multicollinearity with A_g(*road:manufacturing*). Replacing A_g(*road:manufacturing*) by A_g(*road:distribution*) in the model does not significantly alter the results.

5.3. Results

Following the structural equation modeling logic, the assessment of a PLS model follows a two-step approach that involves separate assessments of the measurement model and the structural model (Hair et al., 2006, 2011). All parameters within the model were estimated using smartPLS (Ringle et al., 2005). Figures 4 and 5 show the models for the set of metropolitan area counties and non-metropolitan area counties, respectively. These figures show standardized coefficients based on a path weighting scheme. In addition, t-statistics are shown resulting from bootstrapping to assess the significance of the coefficients.

Consistent with Hair et al. (2011), the number of bootstrap samples was chosen equal to 5000 and the number of cases equal to the number of observations: 1088 in the set of metropolitan area counties and 2021 in the set of non-metropolitan area counties. To indicate that the item weights and standardized coefficients are significantly different from 0, t-statistics should be higher than 1.96, based on a two-sided test and a significance level of 0.05.

As can be seen in figure 4, in the structural model for metropolitan counties, the relationship between continental freight accessibility and logistics employment is not significant. The relationship between intercontinental freight accessibility and continental freight accessibility is significant. A separate model, including the direct relation between intercontinental freight acces-

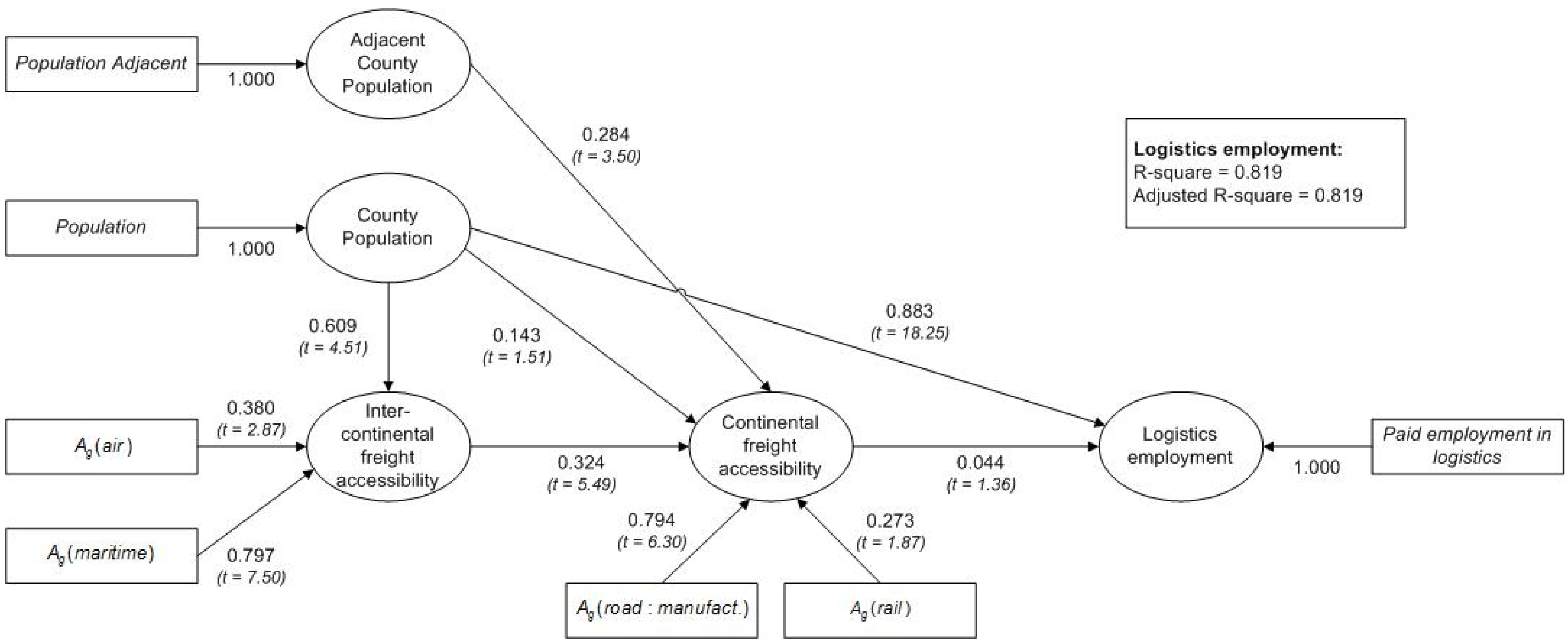

Figure 4: Model with gravity-based accessibility measures for metropolitan area counties. Both the standardized coefficients and the t-statistics are shown on the arrows. T-statistics are found with bootstrapping 1088 cases and 5000 samples.

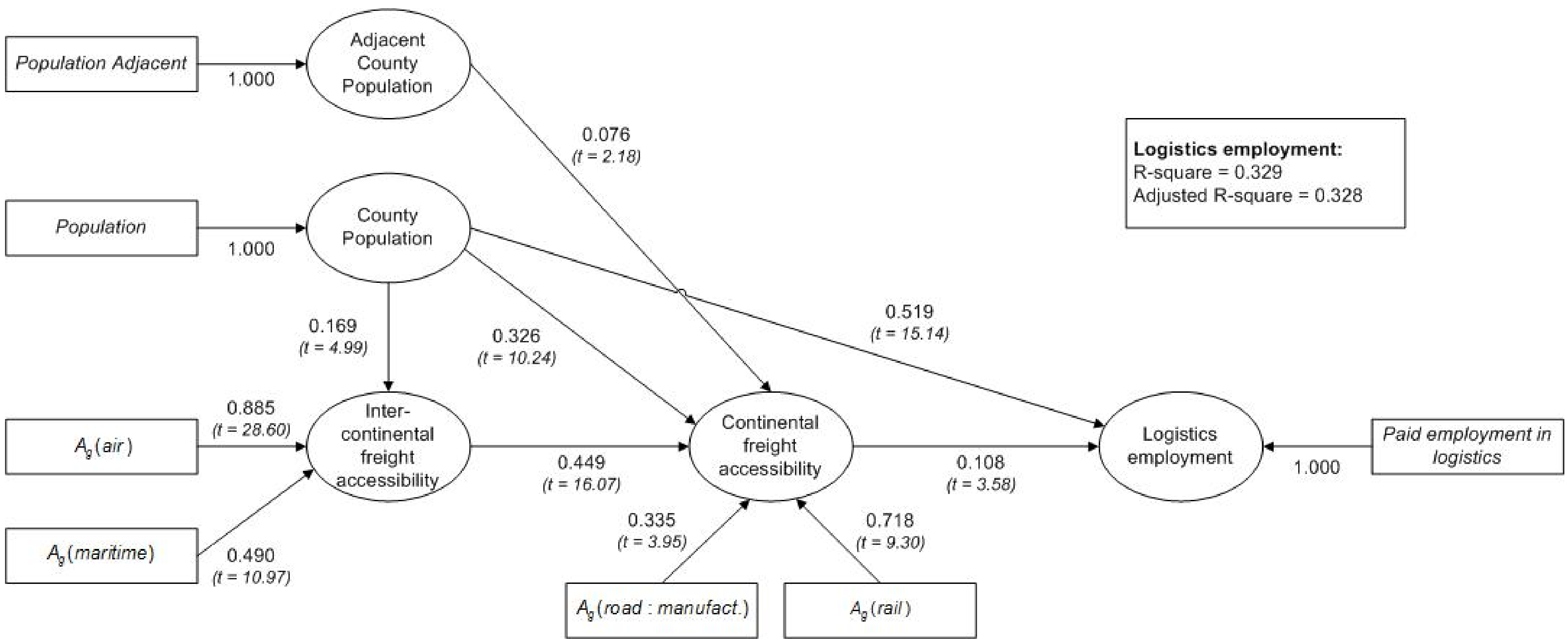

Figure 5: Model with gravity-based accessibility measures for non-metropolitan area counties. Both the standardized coefficients and the t-statistics are shown on the arrows. T-statistics are found with bootstrapping 2021 cases and 5000 samples.

sibility and logistics employment was also analyzed, but the extra relation turned out not to be significant. Hence, in metropolitan area counties freight accessibility cannot be used to explain the level of logistics employment. Figure 5 demonstrates that non-metropolitan area counties are different. Here, the coefficient correlating continental freight accessibility and logistics employment is significant. Again, there is a significant relation between international and continental freight accessibility. Hence, in non-metropolitan areas, freight accessibility can be used to explain differences in county logistics employment. Metropolitan counties on average have a much better accessibility than non-metropolitan counties; the average accessibility of metropolitan counties is 2.5 to 6 times as large as the average accessibility of non-metropolitan counties, depending on the mode of transportation. Hence, the metropolitan counties attract more logistics firms; the average logistics employment in metropolitan counties is ten times as large as in non-metropolitan counties. However, within the set of metropolitan counties, a highly accessible county is not more attractive for logistics firms than an average accessible county, with equal population size. Apparently, there is a certain threshold on accessibility: below the threshold, counties with a better accessibility attract more logistics employment (after controlling for population differences), and above the threshold, better accessibility does not influence the attractiveness anymore.

Another relationship which did not prove significant in the metropolitan counties model is the one between population and continental freight accessibility. However, there is a relationship between population and continental freight accessibility via intercontinental freight accessibility. This relationship is significant. In the non-metropolitan county model all coefficients are significant. Hence, these PLS models show that controlling for population per county is important when the relationship between accessibility and logistics employment is analyzed. In both metropolitan and non-metropolitan counties, differences in county population explain differences in freight accessibility as well as the logistics employment. Adjacent county population only has an effect on continental freight accessibility. We also tested for an effect on logistics employment, but since this was not significant, it was excluded from the models for the sake of simplicity.

No significant relationship was found between accessibility and logistics employment in the metropolitan area counties, while the correlation between the separate accessibility measures and logistics employment was relatively high. However, this relation turned out to be spurious, because it can be explained by the relationship between population and both constructs. In the non-metropolitan area counties there is a positive relationship between accessibility and logistics employment.

The explanatory power, measured with the adjusted R-square of logistics employment, of the model for metropolitan area counties (figure 4) is much higher than the explanatory power of the model for non-metropolitan area counties (figure 5). This is primarily determined by the relation between population and logistics employment, as the standardized coefficient of this relationship is much larger in the former model than in the latter one. Hence, the relationship between freight accessibility and logistics employment is much weaker than the relationship between population and logistics employment.

The results based on gravity-based measures were compared to the results with the density-based measures defined by Bowen (2008). Details are presented in AppendixA. The analysis shows that unlike the gravity-based measures, using the density-based measures results in no relation between freight accessibility and logistics employment, both in metropolitan and in non-metropolitan areas, while bivariate correlations between these variables are all highly significant. Hence, bivariate correlations serve as a good starting point of most analyses, but have to be interpreted carefully. High bivariate correlations between more than two variables can result in conclusions based on spurious relationships. Our analysis suggests that the high bivariate correlation between freight accessibility and warehouse establishments found by Bowen (2008) is at least partially spurious.

6. Conclusion

This paper analyzed the relationship between freight accessibility and logistics employment. We developed a freight accessibility measure that is particularly relevant for logistics companies. Traditionally, accessibility is measured from a passenger perspective, as most of the traffic is passenger related. However, anecdotal evidence suggests that logistics companies are attracted to highly accessible locations (Sheffi, 2012). To be able to measure this relationship, a freight accessibility measure was developed. This measure is based on a gravity model and considers four different modes of transportation: road, air, maritime, and rail. A correlation analysis on a county level in the US suggests that there is a relationship between freight accessibility and logistics employment. However, county population also has a high correlation with both freight accessibility and logistics employment. To test whether the bivariate relationship between freight accessibility and logistics employment is not spurious, a Partial Least Squares model was used. A difference was made between metropolitan and non-metropolitan counties. Results show that population is the most important variable in explaining differences in logistics employment levels, both in metropolitan and non-metropolitan counties. In metropolitan counties, this even results in a non-significant relationship between freight accessibility and logistics employment. A possible explanation may be that counties in metropolitan areas all are relatively accessible, so that firms no longer consider accessibility as a differentiator. In non-metropolitan counties, there was a significant relationship between freight accessibility and logistics employment, after controlling for population.

This paper makes three contributions to the existing literature. First, an accessibility measure was developed that is especially relevant from a freight transport perspective, while existing measures primarily focus on accessibility from a passenger transport perspective. Second, the paper showed that for analyzing relationships between freight accessibility and logistics employment it is important to control for the effect of population differences. As both accessibility and logistics employment have a relationship with population, a bivariate analysis results in a conclusion based on a spurious relationship. In the US, it is shown that this is indeed the case for metropolitan counties. Third, results from the Partial Least Squares model relating freight accessibility to logistics employment, controlling for the effect of the county population, show that highly accessible non-metropolitan counties attract more logistics employment than other non-metropolitan counties.

In this paper, we defined accessibility based on four different modes of transportation, namely road, rail, maritime, and air transportation. From a policy perspective, an interesting follow-up question on this analysis would be whether there is a difference in the use of more sustainable transport modes (rail and maritime) in counties with a higher accessibility to these modes. While in this paper we were interested in the combined level of accessibility, policy makers may be more interested in the attractiveness of counties based on "sustainable accessibility", i.e. whether counties with a good rail and/or maritime accessibility attract (additional) logistics employment. In such an analysis, it is important to measure whether the logistics companies located in these counties also actually use these modes of transport. Hence, additional data are needed for such an analysis.

Appendices

AppendixA. Density-based (rail)road accessibility

Bowen (2008) defined density-based accessibility measures to measure (rail)road accessibility. These measures divide the kilometers of (rail)road per county by the county's area (r_i/s_i). Standardizing this measure results in the following measure $A_{d,i}$:

$$\begin{aligned} A_{d,i} &= \frac{a_{d,i}}{\frac{1}{I}\sum_{j\in I} a_{d,j}} \\ a_{d,i} &= \frac{r_i}{s_i/s_{med}} \end{aligned}$$

with: $A_{d,i}$ = Accessibility (density-based) of county i, r_i = Length of all relevant (rail)roads in county i (in kilometers), s_i = Area of county i (in square kilometers), s_{med} = Median of all s_i (in square kilometers).

To measure road and rail accessibility in this appendix, r_i is equal to the sum of the length of the major roads part of the US principal arterial network (US Department of Transportation, 2011a), and major railroads, owned by the Class I freight railroad companies in the US, respectively.

Table A.1 presents the correlations between logistics employment, population, and the density-based accessibility measures. Generally, the correlation of the gravity-based measures (see table 2) and logistics employment is higher than the correlation of the density-based measures (see table A.1) and logistics employment. For example, for road transport in non-metropolitan areas, the correlation between the gravity-based measure $A_g(road{:}manufacturing)$ and logistics employment is 0.337, while the correlation between the density-based measure $A_d(road)$ and logistics employment is only 0.191.

Table A.1: Pearson correlation coefficients. Correlation coefficients for metropolitan area counties (N = 1088) are shown above the diagonal and correlation coefficients for non-metropolitan area counties are shown below the diagonal (N = 2021).

		(1)	(2)	(3)	(4)	(5)
(1)	Logistics employment		0.904*	0.392*	0.294*	0.241*
(2)	Population	0.565*		0.491*	0.356*	0.188*
(3)	Population in adjacent counties	0.161*	0.388*		0.313*	0.119*
(4)	$A_d(road)$	0.191*	0.271*	0.059*		0.577*
(5)	$A_d(rail)$	0.126*	0.120*	-0.008	0.588*	

* Significant with $\alpha < 0.05$.

The PLS analysis was also conducted with the density-based measures. Figure A.1 and figure A.2 present the PLS models for metropolitan and non-metropolitan area counties, respectively. In these models, $A_g(road{:}manufacturing)$ and $A_g(rail)$ are replaced by $A_d(road)$ and $A_d(rail)$. $A_g(air)$ and $A_g(maritime)$ are still included in the models, as Bowen (2008) used simplified gravity-based measures and no density-based measures for these transport modes. In general, the PLS models with the density-based accessibility measures show many similarities with the PLS models with the gravity-based measures. The most important difference is that with density-based measures, not only there is no relation between freight accessibility and logistics employment in metropolitan areas, there also is no relation between these constructs in non-metropolitan areas. Hence, although the positive correlation between the density-based accessibility measures and logistics employment suggest that there is a relationship between these variables per county, this turns out to be spurious, as it can be fully explained by the relations between these variables and the county population.

AppendixB. Industry codes of the logistics sector in the US

The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in the US to classify business establishments for the purpose of collecting, analyzing, and publishing statistical data (US Census, 2012a). Table B.1 presents the NAICS codes used to identify the logistics sector in the US.

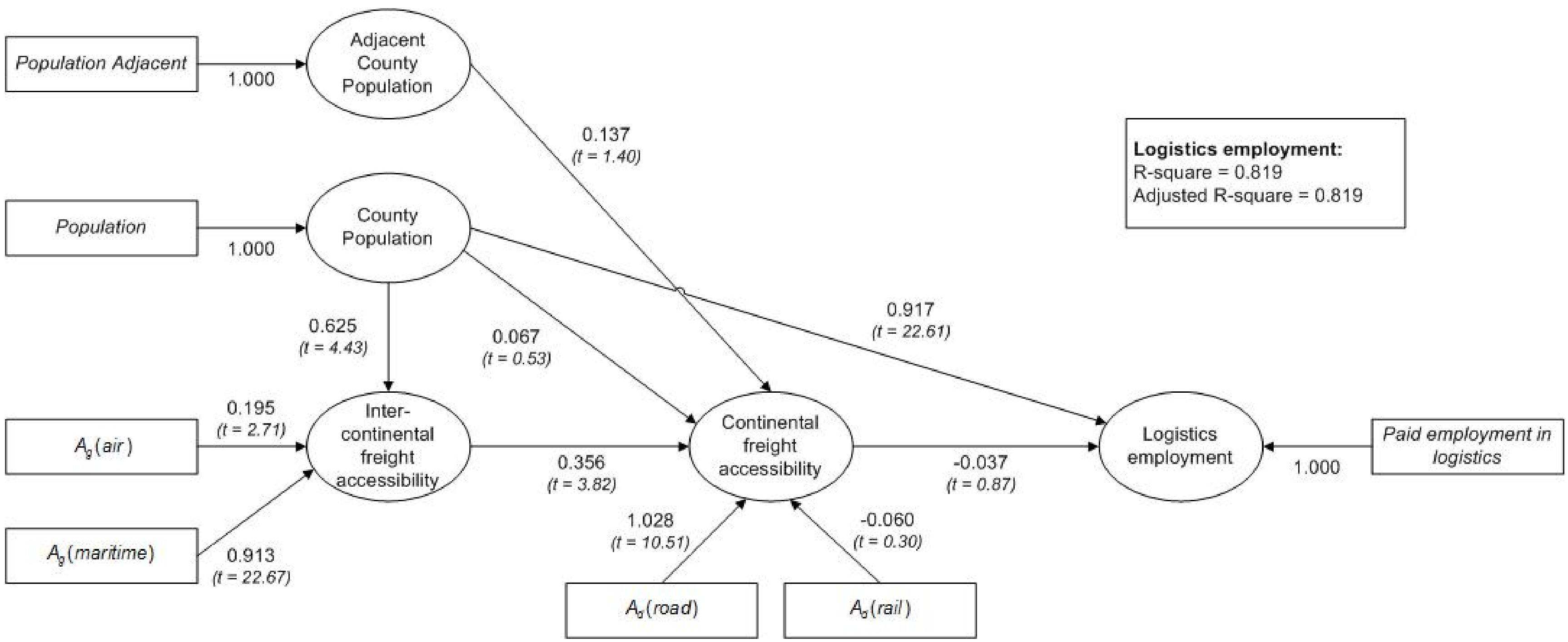

Figure A.1: Model with density-based accessibility measures for metropolitan area counties. Both the standardized coefficients and the t-statistics are shown on the arrows. T-statistics are found with bootstrapping 1088 cases and 5000 samples.

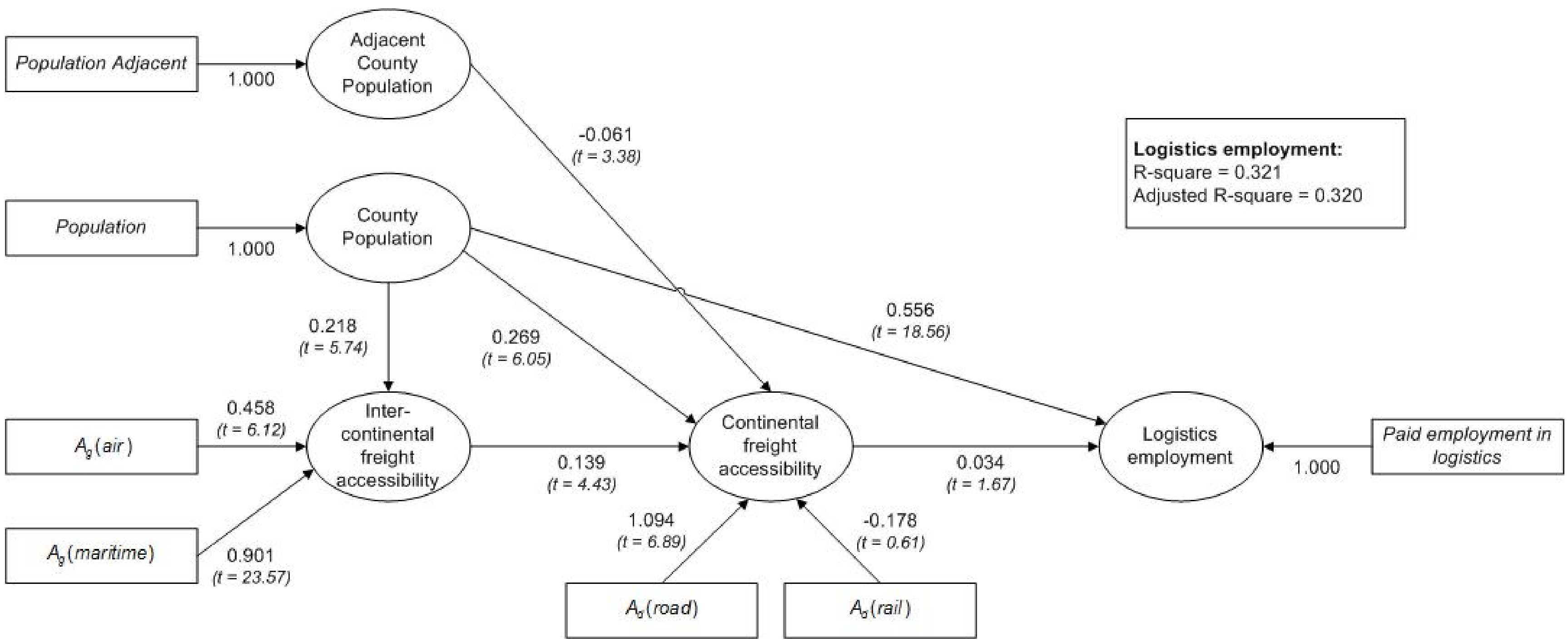

Figure A.2: Model with density-based accessibility measures for non-metropolitan area counties. Both the standardized coefficients and the t-statistics are shown on the arrows. T-statistics are found with bootstrapping 2021 cases and 5000 samples.

Table B.1: NAICS codes used to define the logistics sector

NAICS	**NAICS description**	**% of logistics employment**
481112	Scheduled freight air transportation	0.34%
481212	Nonscheduled chartered freight air transportation	0.20%
481219	Other nonscheduled air transportation	0.18%
483111	Deep sea freight transportation	0.36%
483113	Coastal and great lakes freight transportation	0.68%
483211	Inland water freight transportation	0.55%
484110	General freight trucking, local	6.58%
484121	General freight trucking, long distance, truckload	15.54%
484122	General freight trucking, long distance, less than truckload	8.51%
484220	Specialized freight (except used goods) trucking, local	6.42%
484230	Specialized freight (except used goods) trucking, long-distance	5.15%
488119	Other airport operations	2.19%
488190	Other support activities for air transportation	2.80%
488210	Support activities for rail transportation	0.94%
488310	Port and harbor operations	0.20%
488320	Marine cargo handling	1.85%
488330	Navigational services to shipping	0.40%
488390	Other support activities for water transportation	0.34%
488410	Motor vehicle towing	1.66%
488490	Other support activities for road transportation	0.73%
488510	Freight transportation arrangement	6.60%
488991	Packing and crating	0.68%
488999	All other support activities for transportation	0.30%
492110	Couriers and express delivery services	16.17%
492210	Local messengers and local delivery	1.28%
493110	General warehousing and storage	15.8%
493190	Other warehousing and storage	3.55%

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