Investigating the relationship between regional logistics infrastructure and regional GDP

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Abstract

Many indices (e.g., Logistics Performance Index) provide a framework for evaluating the relative standing of countries in terms of infrastructure quality and performance. However, universal investment in infrastructure is not an efficient way to influence economic growth. It is critical to identify and assess all indicators of infrastructure and focus on developing weak links. With this backdrop, the purpose of this research is to investigate the relationship between regional logistics infrastructure and the regional GDP. This will help to better understand the relative importance of diverse logistics indicators in influencing economic development, and provide insights for policy decision-making.

Keywords: Regional logistics, GDP, partial least squares-structural equation modeling

Introduction

Many indices – such as Logistics Performance Index (LPI) by the World Bank (Arvis et al. 2016), and Global Competitiveness Index (GCI) by the World Economic Forum (Schwab, Sala-i-Martin, and Samans 2017) – exist that measure infrastructure quality and performance of individual countries. These indices provide a valuable framework for evaluating the relative infrastructural positions of several countries. Infrastructure is widely accepted to be positively correlated to economic growth. For example, Sturm, Jacobs, and Groote (1999) found a positive effect of infrastructure investment on gross domestic product (GDP).

Indices such as LPI and GCI provide valuable information for policy makers, industrial associations, companies, and other stakeholders to advocate for the role of infrastructure in enabling economic growth and provide input into the policies needed to support critical infrastructural areas (Arvis et al. 2016). Indices also help to build a common understanding of the strengths/weaknesses and challenges/opportunities across countries or other units of analysis by providing comparable data to address economic and social issues (Schwab, Sala-i-Martin, and Samans 2017).

Logistics is an important component of all economic indices and has been identified as one of the most critical of all infrastructures (Arvis et al. 2016). Further, there is preliminary evidence of positive relationship between logistics infrastructure and economic growth. For example, Fernald (1999) concluded that road building (i.e. an infrastructure component) benefits vehicle-intensive industries and hence can be argued to impact economic growth. More recently, D'Aleo and Sergi (2017) found that the LPI (a measure of logistics infrastructure) and the GCI (that measures the microeconomic and macroeconomic foundations of national competitiveness) together are good predictors of economic growth. Therefore, the primary focus of this research is logistics infrastructure.

While broad country-level indices are suitable for inter-country comparative analysis, there are several limitations for their use in making country-level policy and infrastructural decisions. First, as (Arvis et al. 2016) suggest, "(the indices) *should not be over-interpreted beyond its role as a global benchmark. It is not a substitute for in-depth country diagnoses* (pp. iii)". Second, the country-level indices may not adequately capture domestic concerns such as environmental sustainability or labor and skill shortages, and use of proxy measures (Arvis et al. 2016; Schwab, Sala-i-Martin, and Samans 2017). Third, even within a country, different regions could have unique infrastructure and economic development profiles. In summary, specific indices are needed to make investment and policy decisions at the country and regional levels.

With this backdrop, this research investigates the relationship between logistics infrastructure and GDP at the regional level using Austria as context. The purpose of this research is to investigate the relationship between regional logistics infrastructure and the regional GDP in Austria. The research objectives are to better understand the relative importance of diverse logistics indicators in influencing economic development, and to provide insights for policy and business decision-making.

Logistics infrastructure and the GDP

As a measure for productivity of a region, the GDP indicates the health of the economic mechanism (Dorman 2014). Therefore, the regional GDP gives information of the economic state of a respective region. As such, the GDP is included in almost every index, that measures any aspect of economy, for example, competitiveness, connectedness, and others (Schwab, Sala-i-Martin, and Samans 2017; Ghemawat and Altman 2016).

Logistics infrastructure is the base for transportation and other logistics performances. Infrastructure for different modes includes streets, railway tracks, airports and sea or river ports. Necessary for all modes are logistics service providers, properties and customs offices. Moreover, important resources, such as electricity and fuel, needed for transportation also require their own infrastructure (Chopra and Meindl 2013). While several developing countries work on building their infrastructure, most countries in Europe aim to keep their infrastructure in a good condition (Graefe and Alexeenko 2008). A reliable measurement of the infrastructure quality helps with benchmarking in both cases.

Logistics infrastructure consists of both the physical aspects of logistics such as availability of and access to logistics-related assets as well as economic factors such as logistics-related wages and investments.

Investment in infrastructure has two sides. On one hand, Aschauer (1989) proposed that public investment in infrastructure led to an improvement of efficiency and profitability in the private economy. This accounts for the macro-level view. On the other hand, the micro-level view suggests that large infrastructure projects often come along with underestimating the costs and overrating the benefit (Flyvbjerg, Garbuio, and Lovallo (2009). Further, D'Aleo and Sergi (2017) tested hypotheses involving competitiveness, logistics and economic growth and found that competitiveness measured by the GCI has a positive effect on the GDP, while logistics alone, measured by the LPI, is not a good estimator for the GDP. Together, LPI and the GCI have a significant positive influence on the GDP.

Based on the above discussion, in this paper, the impact of two constructs – the transportation infrastructure and the economic foundation for logistics – on the regional GDP is investigated. Figure 1 presents the theoretical model.

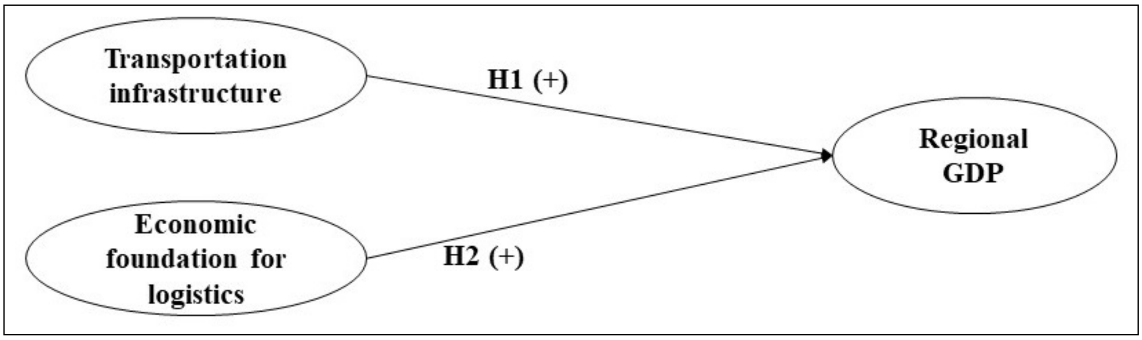

Figure 1 - Theoretical model of regional logistics infrastructure and regional GDP

Transportation infrastructure

The transportation infrastructure refers to availability of and access to transportation modes and facilities. It includes proximity to intermodal hubs, river ports, airports, railway terminals, and connections to highways, as well as the lengths of road and railway networks. Fernald (1999) found that road-building positively influenced especially the vehicle-intensive industries from the 1950s to the 1980s. This development cannot be extended arbitrarily since reaching a certain threshold, the effect vanishes. However, this result implies that a proper network of roads is needed which is likely to hold also for railway, aero transport and sea/river shipping. Therefore, it is proposed, that quality and quantity up to the threshold of transportation infrastructure has a positive effect on the GDP.

H1: Regional transportation infrastructure has a positive effect on the regional GDP.

Economic foundation for logistics

The economic foundation for logistics refers to wages and investments related to logistics. It includes salaries earned by those in the sector and the investment in logistics-related real estate such as warehouses. Moreover, the density of logistics companies is a part of this construct. If the economic foundation for logistics is good, the logistics performance is higher, meaning that the offerings are more diverse and the quality is better, although the costs tend to be higher in such regions (Jena and Seth 2016). Additionally, the competitiveness of regions with a good economic foundation for logistics would be higher in comparison to other regions. Following D'Aleo and Sergi (2017) a good state of the logistics economy should result in a higher GDP.

H2: The economic foundation for logistics has a positive effect on the regional GDP.

Method

In this section, the method followed to collect data and test the hypotheses is described.

Data collection

In the course of developing a logistics indicator, the Austrian Ministry of Transport, Innovation and Technology together with the University of Applied Sciences Upper Austria, collected the data on 73 indicators for 35 regions of Austria. Initially, nine international indices, including the LPI and the GCI, were used to come up with 348 indicators. In consultation with 70 participants in a series of four workshops, these indicators were evaluated and rationalized, and new region-specific indicators were added. The participants included stakeholders affected by the characteristics of logistics infrastructure such as, logistics, trade, industry, and government associations of Austria. Overall, 73 indicators were operationalized. The data for these indicators for each of the 35 regions of Austria was obtained from publicly available sources such as Statistik Austria, Eurostat, and Wirtschaftskammer Österreich. The data is based on the NUTS 3 classification of the European Commission (2015), which breaks down the economic territory of the European Union into regions for regional statistics. Altogether, Austria is structured into 9 states, 118 districts and 2,100 municipalities. Hence, the NUTS 3 regions are a combination of districts and each state is divided into 2 to 7 Nuts 3 regions. Figure 2 shows the count of logistics service providers, as an example, for all NUTS 3 regions of Austria.

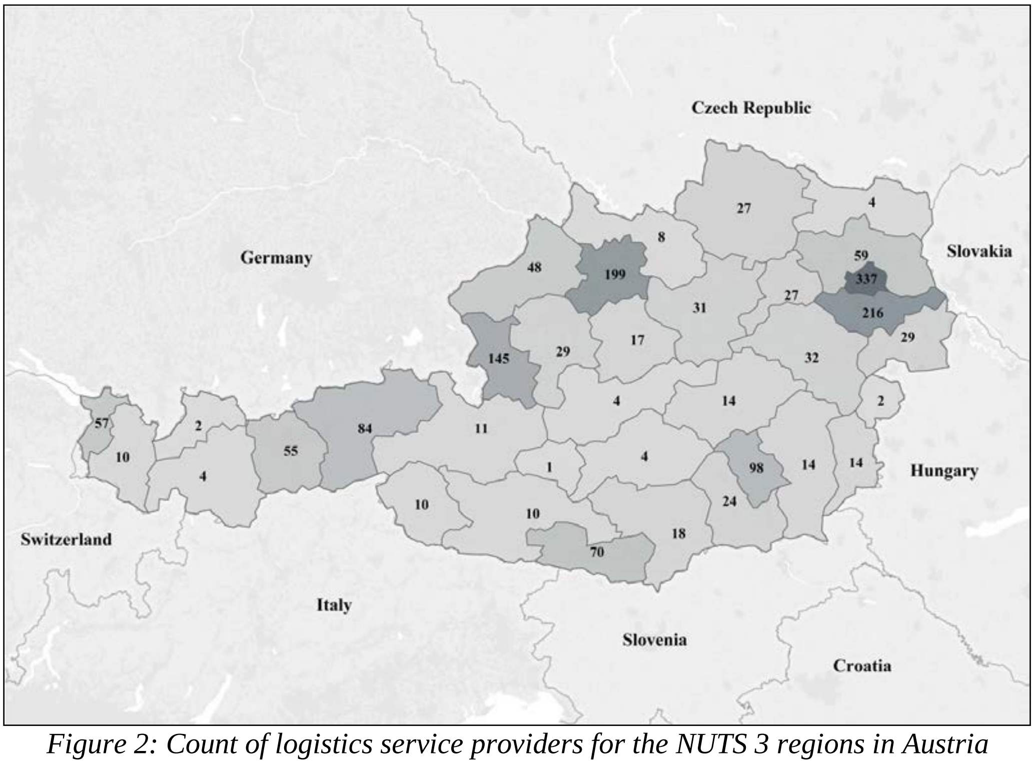

Figure 2: Count of logistics service providers for the NUTS 3 regions in Austria

The initial set of variables on which the data was collected is presented in table 1. There were no missing values in the data.

Table 1: Variables in the data set

NO	ITEM	NO	ITEM
1	activity rate	31	educational institutes for logistics
2	availability of broadband	32	export rate
3	average hours of traffic-jam per kilometer	33	grade of electrification of the railway network
4	average price for potential properties for logistics	34	gross investment to property per company in category of traffic (ÖNACE 2008-H Verkehr)
5	average size of existing properties for logistics	35	gross salary on average in the sector of traffic (ÖNACE 2008 Gruppe H)
6	average travel time to highway connection	36	import rate
7	average travel time to railway-terminal	37	intensity of new company launches
8	average travel time to the next airport	38	intensity of patents
9	average travel time to the next multimodal hub	39	length of the rivers, where goods can be shipped
10	average travel time to the next sea- or riverports	40	length of highways with classification 'E'
11	barrages on important connections	41	length of pipelines
12	commuter into the region	42	length of the railway network
13	commuters out of the region	43	lorry toll on average
14	commuters within the region	44	number of employees per company in the sector of traffic (ÖNACE 2008-H)
15	cost for electricity grid	45	number of leading companies in the region
16	credit-rating of the state	46	number of stopping places for trucks on highways
17	delay of transport due to political reasons	47	opening hours of customs authorities
18	delicts against someone else's assets	48	price of diesel
19	density of charging stations	49	price of water
20	density of companies per 1000 capita in category of traffic (ÖNACE 2008-H Verkehr)	50	public deficit
21	density of logistic service providers	51	public sponsorship
22	density of residential population	52	public sponsorship (EU)
23	density of the railway network	53	quality of electricity supply
24	density of the road network	54	quality of tertiary institutions
25	development of residential population	55	quantity of airports
26	distance to highwayconnection	56	quantity of centers of technology
27	distance to railway-terminal	57	quantity of connections to the highway
28	distance to the next airport	58	quantity of logistic service providers
29	distance to the next multimodal hub	59	quantity of multimodal hubs
30	distance to the next sea- or riverport	60	quantity of railway-terminals

Continuation of table 1: Variables in the data set

NO	ITEM	NO	ITEM
61	quantity of sea- or riverports	68	regional GDP per capita
62	ratio of employees in knowledge-intensive services	69	resident population
63	ratio of employees in traffic to total employees	70	sum of sponsorship
64	ratio of foreign investment (equity) with respect to GDP	71	total size of existing properties for logistics
65	ratio of foreign owners of companies	72	turnover per company in traffic
66	ratio of graduation	73	unemployment rate
67	ratio of potential properties for logistics to space of permanent settlement		

Measurement of the variables

The 73 variables of the data set were assigned to the constructs under investigation. If an item did not fit an existing construct, it was removed. Three researchers participated in the effort. This resulted in 42 items that were included for statistical testing. 14 items were eliminated because of the problem of multicollinearity (Hair et al. 2017). For example, the average travel time to the next hub correlates highly with the distance to the next hub and is therefore excluded. Finally, five items for infrastructure and three items for logistics economy were retained. These are listed in table 2.

Table 2: Descriptive analytics of the variables used for the measurement

Code	Indicator	Min	Average	Max	Standard Deviation
GDP	regional GDP per capita [1,000 €]	20.20	34.76	48.90	8.27
ECO_1	gross investment to property per company in category of traffic (ÖNACE 2008-H Verkehr) [1,000 €]	55.10	138.36	321.17	91.95
ECO_2	number of companies per 1000 capita in category of traffic (ÖNACE 2008-H Verkehr) [#]	1.40	1.65	2.60	0.35
ECO_3	gross salary on average in the sector of traffic (ÖNACE 2008 Gruppe H) [1,000 €]	25.58	31.40	38.94	4.02
INFRA_1	quantity of logistic service providers [#]	1.00	48.97	337.00	72.35
INFRA_2	total size of existing properties for logistics [1,000 km^2]	0	82.95	684.80	138.33
INFRA_3	distance to the next multimodal hub [km]	-108.24	-46.36	-1.90	32.32
INFRA_4	quantity of multimodal hubs [#]	0.00	0.43	3.00	0.81
INFRA_5	distance to the next airport [km]	-148.43	-60.38	-3.61	35.66

Data analysis

To analyze the data we used partial least squares (PLS) – structural equation modeling (SEM). Nitzl and Chin (2017) gave a valuable discussion on the different aspects of PLS-

SEM. In this section, we give a summary of the relevant details for this paper, followed by a description of the measurement of the constructs.

Comparing to regression analysis, SEM is more flexible and follows a more holistic approach, allowing for latent variables – constructs that cannot be measured directly (Hair et al. 2017). In general, there are two different methods provided by SEM. The covariance-based approach and the variance-based, PLS approach. The latter is the better choice for formatively measured constructs, since it is composite-based, meaning that different items are combined to a new construct (Sarstedt et al. 2016). PLS-SEM is also the better method for explanatory analyzes and when the sample size is small (Reinartz, Haenlein, and Henseler 2009). The goal of PLS is to calculate weights, such that the construct score is high and correlates maximally with the other constructs (Esposito Vinzi et al. 2010).

The constructs of the model proposed above are suitable for a formative measurement. Transportation infrastructure is the sum of its different parts, e.g., modes – which is just the definition of formative measurement. For the economic foundation for logistics, it is a bit more complicated to decide if the measurement is formative or reflective. In a reflective measurement, the items should correlate amongst them, which is not the case for the items used in this paper. The correlation between ECO_1 and ECO_2 is below 0.5, the correlation between ECO_2 and ECO_3 is at 0.25 and only the correlation between ECO_1 and ECO_3 is at a higher value of 0.75. Therefore, and because of the low sample size of 35 regions, the PLS version of SEM was chosen.

We used SmartPLS-Software Version 3 to calculate the model and evaluate the hypotheses (Ringle, Wende, and Becker 2015).

Findings

To examine the construct measurements, we chose the no sign change option with 500 bootstraps and the bias-corrected (BCa) bootstrapping method. Referring to multicollinearity, the variance inflation factor (VIF) was below five for all items, where five is the critical value. As can be seen in table 3, the outer weights for each item is non-significant, i.e. zero is included in the confidence interval. Nevertheless, the outer loadings (table 4) are significant for all items, meaning that the items are absolutely important but not relatively important. The path coefficients and t-values from the bootstrapping can be seen in figure 3.

The assessment of the inner model is also pictured in figure 3. Since the path coefficients of both connections are significant, H1 and H2 can be accepted (table 5). The coefficient of determination at 0.6 shows the explanatory power of the model. The relative effects of the constructs show a substantive impact of both relations (table 6).

Table 3: Evaluation of the construct measurements: outer weights

Outer weights	Weights	2.5%	97.5%
		Confidence interval	
INFRA_1 -> Transport Infrastructure	0.403	-1.004	1.267
INFRA_2 -> Transport Infrastructure	0.222	-0.800	1.205
INFRA_3 -> Transport Infrastructure	-0.019	-0.736	0.651
INFRA_4 -> Transport Infrastructure	0.303	-0.461	0.848
INFRA_5 -> Transport Infrastructure	0.265	-0.230	0.886
ECO_1 -> Status of the Logistics Economy	0.786	-0.135	1.527
ECO_2 -> Status of the Logistics Economy	0.232	-0.447	0.751
ECO_3 -> Status of the Logistics Economy	0.130	-0.716	0.940

Table 4: Evaluation of the construct measurements: outer loadings

Outer loadings	Original Sample	2.5%	97.5%
		Confidence Interval	
INFRA_1 -> Transport Infrastructure	0.917	0.849	0.970
INFRA_2 -> Transport Infrastructure	0.887	0.764	0.981
INFRA_3 -> Transport Infrastructure	0.637	0.114	0.893
INFRA_4 -> Transport Infrastructure	0.847	0.627	0.984
INFRA_5 -> Transport Infrastructure	0.712	0.422	0.940
ECO_1 -> Status of the Logistics Economy	0.974	0.909	0.999
ECO_2 -> Status of the Logistics Economy	0.577	0.039	0.914
ECO_3 -> Status of the Logistics Economy	0.772	0.277	0.994

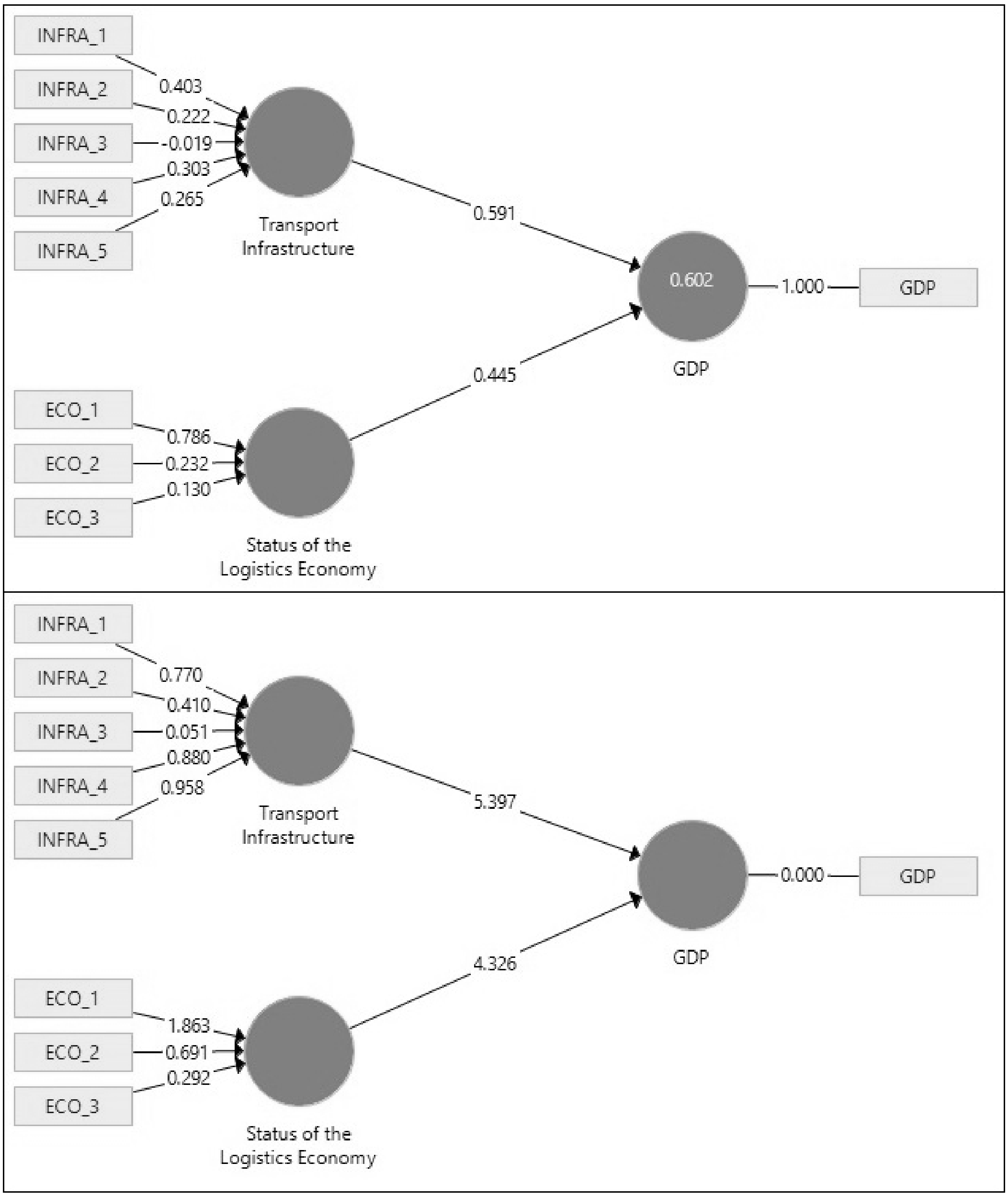

Figure 3: Estimation of the model in SmartPLS 3, upper: with the path coefficients, lower: with t-values from bootstrapping

Table 5: Significance of the inner model

Inner model	Path coefficients	2.5%	97.5%
		Confidence interval	
Status of the Logistics Economy -> GDP	0.445	0.270	0.656
Transport Infrastructure -> GDP	0.591	0.319	0.748

Table 6: Relative effects of the constructs

Relative effect	GDP
Status of the Logistics Economy	0.492
Transport Infrastructure	0.866

We are still in the process of understanding the data. More inferences will emerge as data analysis progresses.

Research limitations/implications

This research presents a theoretical framework to establish and test relationships between transportation infrastructure, economic foundation for logistics, and the regional GDP. All relationships are significant. While prior research has suggested these relationships at the country level, this research provides an empirical test in a regional context.

This research provides a framework that regional public officials may use to make decisions related to investments in logistics infrastructure, education, research, innovation, and technology to improve regional GDP. Given that resources are limited, the framework can help with prioritizing future investments. At a higher level, the results may provide national politicians and policy makers a comparative assessment of the existing state of logistics infrastructure in different regions.

Since the data covers Austria, the findings and indicators are limited to Austria. However, the framework can be extended to other countries and new indicators may easily be incorporated.

Originality

This research explores the connection between regional logistics infrastructure and the regional GDP. While there are multiple national indicators, this original research delves deep into development of regional logistics indicators using a highly rigorous method with high internal validity and generalizability.

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