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Logistics-related determinants of regional gross domestic product - an exploratory investigation

Matthias Winter[1]
Logistikum, University of Applied Sciences Upper Austria, Steyr, Austria.

Ila Manuj[2]
Department of Logistics and Operations Management, University of North Texas, Denton, USA.

Markus Gerschberger[3]
Josef Ressel Centre for Real-Time Value Network Visibility, Logistikum, University of Applied Sciences Upper Austria, Steyr, Austria.

Existing research suggests a link between a country's infrastructure quality and its economic performance. However, no country can invest in all types of infrastructure across the country. Therefore, it is critical to identify and assess multiple indicators of infrastructure for regions within a country and focus on improving infrastructure as identified by the weak indicators. Research investigating the determinants of regional wealth and economic growth is limited. In this comprehensive research including all 35 regions in Austria, we began by evaluating the relationship between logistics-related infrastructure and regional gross domestic product. In the process, other indicators, and mediators such as knowledge infrastructure, business attractiveness emerged as impacting gross domestic product. The findings help to better understand the relative importance of diverse logistics indicators influencing regional economic development and provide insights for policy decision-making.

Keywords: *gross domestic product (GDP), logistics infrastructure, partial least squares – structural equation modelling, regional logistics.*

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[1] A: Wehrgrabengasse 1-3, 4400 Steyr, Austria T: +43 5 0804 33225 E: matthias.winter@fh-steyr.at
[2] A: 1155 Union Circle #311160 Denton, Texas 76203-5017 USA E: ila.manuj@unt.edu
[3] A: Wehrgrabengasse 1-3, 4400 Steyr, Austria T: +43 5 0804 33265 E: markus.gerschberger@fh-steyr.at

1. Introduction

The Gross Domestic Product (GDP) of any country, or national GDP, is defined as the total of services and goods produced in that country over one year (Dorman, 2014). The GDP as a measure was developed in the 1920s and 1930s to assess whether the implemented policies were helping to overcome the great depression. The regional GDP is the regional equivalent to the national GDP. For example, if a country is divided into states, then the total of GDP at the state-level (regional GDPs) over each state of a country will amount to the national GDP. National GDP has been shown to impact social and economic outcomes. For example, Arnold and Blöchinger (2016) investigated the development of inequality in OECD countries and found that regional GDP correlates positively with education, innovation, and carbon-di-oxide emissions. However, research investigating the factors affecting regional GDP is limited.

In this paper, we focus specifically on logistics-related determinants of regional GDP. 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). For example, Logistics Performance Index (LPI) is a measure of logistics infrastructure by the World Bank (Arvis et al., 2016) used to benchmark the logistics performance of all countries over the world. The Global Competitiveness Index (GCI), an index that measures the microeconomic and macroeconomic foundations of national competitiveness, by the World Economic Forum (Schwab et al., 2017) includes several items related to logistics. There is some 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 LPI has a mediator effect on the relationship between the GCI and the GDP. Sturm et al. (1999) found a positive effect of transportation infrastructure investment on gross domestic product. Due to the increasing globalization and the eastward enlargement of the EU, logistics will be a crucial factor to strengthen Europeans economy (D'Aleo & Sergi, 2017). Therefore, it is critical to examine the role logistics and related infrastructure plays in increasing regional GDP.

Indices such as LPI and GCI provide valuable information for policy makers, industrial associations, companies, and other stakeholders for: (a) evaluating the relative infrastructural positions of several countries, (b) advocating for the role of infrastructure in enabling economic growth, and (c) providing 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 et al., 2017).

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 (Arvis et al., 2016; Schwab et al., 2017). Third, within a country, different regions could have unique infrastructure and economic development profiles and may require different interventions from the government. In summary, specific indices are needed to make investment and policy decisions at the regional levels.

The importance of logistics infrastructure is evidenced by its inclusion in several global indices. However, a review of the literature reveals that not much research exists to inform policy decisions related to regional logistics infrastructure, and if and how much does logistics infrastructure actually affect regional GDP. To fill this gap, the purpose of this research is to develop a theoretical model to investigate the relationships between logistics-related determinants of regional GDP. The research objectives are to: (a) identify the key logistics-related infrastructural elements at the regional level, (b) identify elements that affect logistics infrastructure, (c) rank order the relative importance of different types of logistics infrastructure, and (d) investigate if and which aspects of logistics-related infrastructural elements affect regional GDP. The main contribution of this research lies in providing empirical evidence to guide logistics-related infrastructural investments and policy decisions.

2. A Theoretical model of regional GDP

A framework for making location decisions (Lopez & Henderson, 1989) provides some insights into how logistics infrastructure and other infrastructure affect the GDP and the attractiveness of a region for business investment. It suggests that regions with better infrastructure will attract more investment, since better infrastructure facilitates production, retail and transportation. Eventually, if more companies choose a location in a certain region, it will generate more economic output and hence will lead to an increased regional GDP (Hodge et al., 2003). Not surprisingly, governments at different levels endeavor to make their countries, regions, and cities attractive to people and businesses. Globalization has reached a scale like never before (Ghemawat & Altman, 2016). However, within a country, not all regions are similar in terms of infrastructures, such as economic, political, and logistics. Therefore, not just countries but individual regions within countries need to be able to attract companies and workforce.

Many factors affect the attractiveness of a region from an industrial perspective. These include access to and number of consumers, cost and availability of space, access to and cost of transportation modes, quality and network of transportation infrastructure, access to or proximity to public authorities and administration, availability of required workforce, political structures which may permit less or more of strikes, corruption, etc. (Rymarzak & Siemińska, 2012; Coyle et al., 2017). While there is a general understanding that density of people, companies, and institutions drives economic growth (D'Aleo & Sergi, 2017), not many empirical studies exist to support or refute this view. Overall, it may be inferred that understanding the determinants of regional GDP is important for progress of both regions and the country. The theoretical model of regional GDP developed and tested in this research is presented in Figure 1.

Figure 1. *Theoretical model of logistics-related determinants of regional gross domestic product*

In this paper, we argue that logistics infrastructure affects is associated with the attractiveness of a region for business investment, which in turn correlates with the GDP. Moreover, logistics infrastructure correlates with knowledge infrastructure. The following discussion focusses on different aspects of the model and presents arguments in support of the relationships depicted in Figure 1.

To explore what makes a region attractive for people and companies, extensive and rich literature investigating facility location decisions for companies (e.g. Carod, 2005; Boudier-Bensebaa, 2005; Coughlin & Segev, 2000; Lopez & Henderson, 1989) was explored. In line with the purpose of the paper, there was an emphasis on logistics and logistics related infrastructure. Various types of infrastructure are always a part of such literature. For example, Lopez and Henderson (1989) conducted a survey, asking for the importance of 41 factors for location choices for food processing plants. The factors were grouped in the six business categories: market, infrastructure, labor, personal, environment and fiscal policy. The infrastructure category was ranked at the second place right after the market category. It included items such as cost of land, availability of an existing facilities, and utility costs. Also, Coughlin and Segev (2000) found transportation infrastructure to be a determinant for location decision when examining locations of new foreign-owned plants. Carod (2005) found that instead of population, the concentration of jobs in a municipality attracts more companies. Moreover, the proximity of a town to the next capital has an impact on the decision for a new industry location.

Overall, the major common categories of infrastructure include – transportation, energy, water, financial services, health, knowledge, and education (Sofman, 2017). Further, infrastructure could be hard (i.e., physical networks necessary for functioning of regions) or soft (i.e., institutions that help maintain economic, health, and social standards). In line with the purpose of this research, we focus both on specific hard infrastructure (namely, logistics infrastructure) and soft infrastructure (namely, knowledge) which are most relevant to an attractive business environment.

Logistics infrastructure, consisting of basic transportation modes and logistics service providers, is an important factor for facility location decisions (Lopez & Henderson, 1989; Hodge et al., 2003). 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.

Transportation and logistics service infrastructure is expected to attract businesses. For example, a study by the Transportation Research Board for the North Country of New York concluded, "The analysis shown in this paper clearly demonstrates that there is potential for transportation improvements to lead to the attraction of business to the North Country region." (Hodge et al., 2003). In the Lopez and Henderson (1989) article mentioned earlier, several logistics items ranked high. For example, proximity to distribution centers was ranked on seventh and availability and cost of truck and rail services was ranked nineteenth.

Another type of infrastructure, closely related to logistics, that is related to locational determinants and of economic activity (which in turn drives GDP) is the knowledge infrastructure. Knowledge infrastructure refers to institutions that provide the workforce and/or knowledge to support business. Such institutions, such as universities and Research and Development labs, also cause knowledge spill-over effects (Lehmann & Menter, 2016). Knowledge spillover causes the knowledge from education institutes to spillover to the businesses. Knowledge spill-over encourages firms to locate near other firms so take advantage of a shared pooled market for skilled labour and facilitate technological exchange and is crucial for location choices (Boudier-Bensebaa, 2005).

Regional wealth is influenced by universities as sources of knowledge (Lehmann & Menter, 2016), which gives strong evidence that knowledge in general is important for regional development. Universities are usually placed in urban areas, but smaller educational institutes and centers of technology are also placed in smaller regions. They all contribute to the knowledge infrastructure and, therefore to regional wealth. Educations institutions provide skilled labor and labor availability was found to be an important factor for the attraction of inward foreign direct investment (FDI) by Boudier-Bensebaa (2005), when assessing the determinants of FDI for Hungarian regions.

From the above discussion, it can be gathered that that knowledge infrastructure affects the location of different types of infrastructure (including logistics infrastructure) and affects the attractiveness of a region for a business. Therefore, it is hypothesized:

H1: Knowledge infrastructure has a positive effect on logistics infrastructure.

H2: Knowledge infrastructure has a positive effect on attractiveness for business investment of a region.

In the report on competitive transportation in Europe (European Commission, 2014), the example of the Øresund bridge between Malmö and Copenhagen was used to emphasize the importance of logistics infrastructure for regional development. The report mentioned, "This link has contributed to an increase in economic traffic between the two sides and led to significant benefits for local regional development." (p. 7). Bergqvist (2009) conducted a case study in a small region of Sweden, triggering the importance of regional logistics capabilities. He says, "The process of developing logistics capabilities is as much a competitive means as a positive contributor to attractiveness of the region." (p. 63).

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. A proper network of roads, railways, airports, and sea/river ports is needed to attract businesses to a region. If the foundation for logistics is good, the logistics performance is higher because of wider variety and quality of offerings, although the costs tend to be higher in such regions (Jena & Seth, 2016). Therefore, the competitiveness of regions with strong infrastructure foundations in attractive businesses is higher in comparison to regions with weaker infrastructure.

Based on the above discussion, it can be inferred that logistics infrastructure will affect how likely a business is to locate or invest in a given area. Therefore, we propose

H3: Logistics infrastructure has a positive impact on attractiveness of a region for business investment.

The GDP is a measure for productivity of a country or region indicates economic health (Dorman, 2014). GDP is calculated as the market value of all final goods and services produced within a region in a given period of time. The regional GDP gives information of the economic state of a respective region. GDP is included in almost every index, that measures any aspect of economy, for example, competitiveness, or connectedness (Ghemawat & Altman, 2016; Schwab et al., 2017). Concentration of business in an area improves the availability and variety of jobs, educational and lifestyle opportunities, other business partners, and consumers (Lehmann & Menter, 2016). These things in turn drive the GDP of a region (Biktemirova et al., 2015). Overall, it is argued that if a region is able to attract business institutions, it is likely to experience an increase in GDP.

H4: Attractiveness for business investment has a positive effect on regional GDP.

3. Methodology

To test our model and hypotheses, we selected Austria as the context of our study for three reasons. First, Austria is highly representative of the EU in terms of educational level and dual learning opportunities. There are different educational opportunities, which are offered in various school types as well as through working in companies with simultaneous training towards the university entrance level. In addition, a wide range of secondary and tertiary education programs are available. Second, it lies in the middle of Europe and therefore, many transit routes go through it. Especially routes for crossing the Alps through Austria are of major interest. This is supported by the fact, that it is connected to three different Ten-T corridors (Bellodi et al., 2018) who are the main trucking routes via Europe. Finally, due to access to policy makers and other organizations, the authors were able to secure complete data on all regions of the country. In the rest of this section, the method followed to collect data and test the hypotheses is described. The method is summarized in Figure 2.

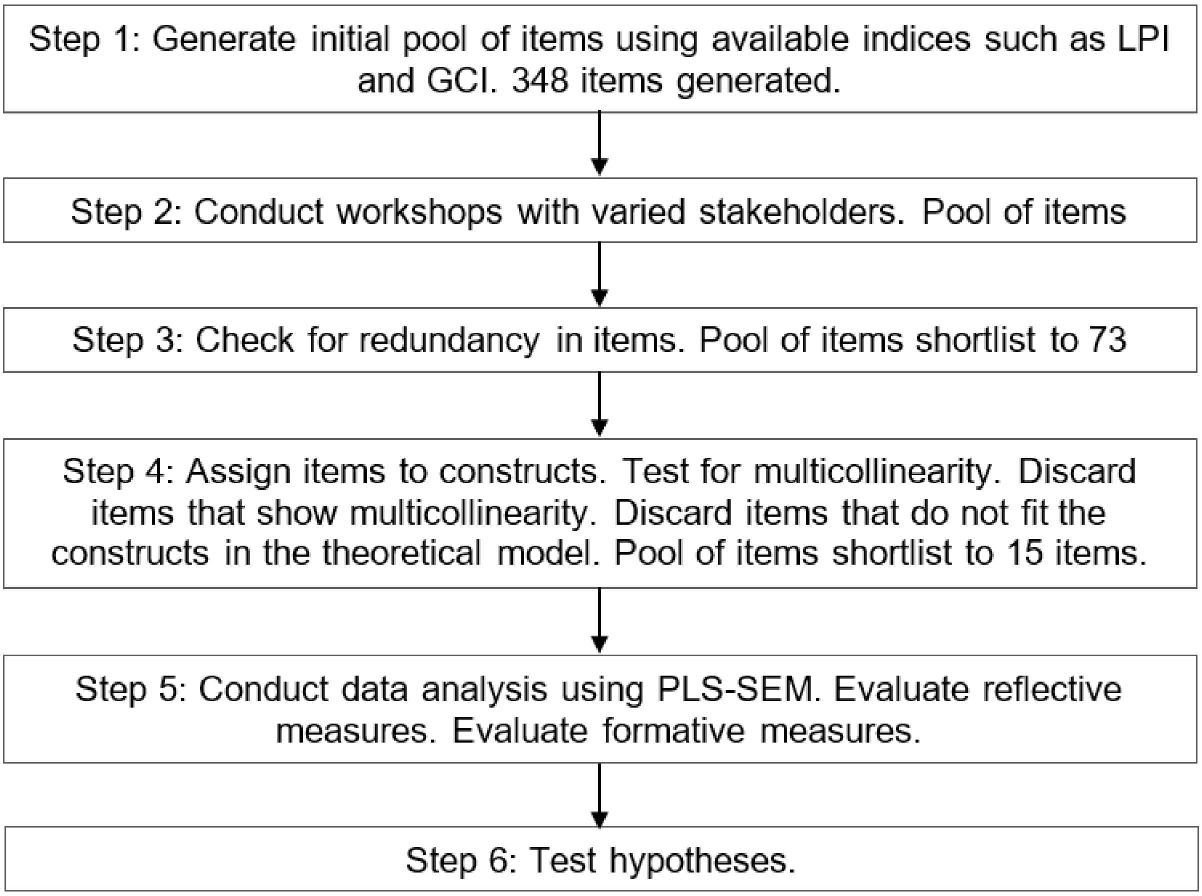

Figure 2. *Process of Generating and Selecting Items*

3.1 Data collection

To develop the items for measuring the constructs in the model, the authors developed, adapted, and/or adopted multi-item measures to evaluate each construct based on Min and Mentzer (2004). First, nine international indices, including the LPI and the GCI, were used to come up with 348 indicators. Further, a series of geographically distributed workshops to capture the nation-wide opinion was held with 70 participants who helped evaluate the items, suggested new region-specific indicators, and helped develop the model. The participants included stakeholders affected by the characteristics of logistics infrastructure such as members of logistics, trade, industry, and government associations of Austria. At this step, we evaluated if the stakeholders perceived each indicator to directly or indirectly represent the constructs in the model at the regional level. We ended up with 117 indicators. Next, we removed redundant items (i.e., kept only unique items), ensured that we captured the breadth of the construct, and explored the availability of secondary data. At this point, 73 indicators were shortlisted. These 73 indicators were imported into Smart-PLS Software and considered for testing the model. Due to the small data set comprising only 34 regions, we tried to keep the model as sparse as possible by reducing multicollinearity; multicollinearity was a problem for several indicators. Therefore, besides relying on the quantitative analysis, the model, constructs, and the set of indicators was shared with two academic experts and two industry experts. Based on quantitative analysis and expert input reduce multicollinearity while preserving the breadth of the construct, a set of 15 indicators comprising of 23 variables was finalized. The variables and calculations of indicators are presented in the appendix. Data from different sources was available with a different time lag; for some sources it could be up to 3 years. At the time of data analysis for this research, the complete data was available for 2017. The authors partnered with the Austrian Ministry of Transport, Innovation and Technology, and collected the data on indicators related to logistics, knowledge, regional characteristics, and GDP for regions of Austria; all 35 regions of Austria are included. The data for these indicators for each of the 35 regions of Austria was obtained from the Austrian ministry and from publicly available sources such as Statistics Austria, Eurostat, and the Austrian Economic Chambers. The data is based on the NUTS-3 (Nomenclature des Unités Territoriales Statistiques, that translates to Nomenclature of Territorial Units for Statistics) classification of the European Commission (2015). NUTS 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. The NUTS 3 regions are a combination of districts, and each state is divided into 2 to 7 NUTS 3 regions. Figure 3 shows all NUTS 3 regions of Austria.

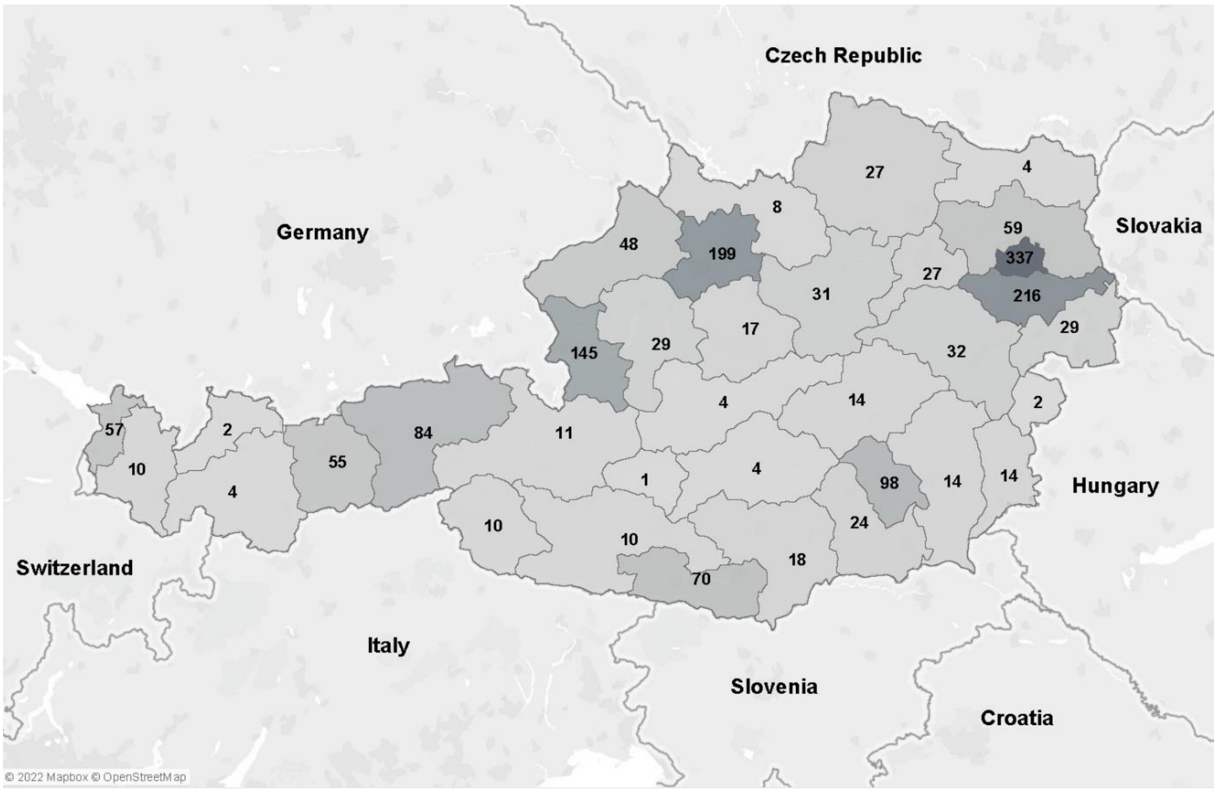

Figure 3. *Regions of Austria*

3.2 Measurement of the constructs

The resulting list of indicators was tested for 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, ten indicators were retained for the analysis – two to four for each construct except GDP, which was measured as a single item. The items are listed in Table 1.

Table 1. Descriptive Analytics of the Variables Used for the Measurement

Construct	Indicator	Min	Average	Max	Standard Deviation
Regional GDP	Regional GDP per capita [1,000 €]	20.20	34.39	48.90	8.10
Logistics infrastructure: Dens_Hub	Density of multimodal hubs = No. of multimodal hubs/Area of permanent settlement [1/1,000km²]	0.00	0.20	1.72	0.41
Logistics infrastructure: Dens_E-HwNet	Density of highways with classification 'E' = length of highways/Area of the region [km/1,000km²]	0.00	40.46	126.70	30.31

Logistics infrastructure: Dens_RailNet	Density of the railway network = Length of network/ Area of the region [km/1,000km²]	1.40	10.04	29.80	6.46
Logistics infrastructure: Dens_LSP	Density of logistic service providers = No. of providers/ Area of the region a [nr./1,000km²]	1.00	22.60	146.40	35.37
Knowledge infrastructure: Num_Edu	Number of educational institutes for logistics	0.00	0.88	6.00	1.37
Knowledge infrastructure: Dens_Tech	Density of centers of technology = No. of centers/ Area of the region [1/1,000km²]	0.00	0.72	3.30	0.84
Attractiveness for business investment: Avg_PropPrice	Overall average price for all municipalities = potential price for properties for logistics in a municipality weighted by the area of the municipality [€/km²]	19.20	95.30	318.20	76.28
Attractiveness for business investment: Dens_Comp	Density of companies =Number of companies/Area of permanent settlement [1/km²]	3.10	16.33	56.50	12.47
Attractiveness for business investment: Commuter-Index	Commuters index [%] = No. of people employed in the region/No. of people living in the region (excludes, kids, retirees, and other unable to work)	0.79	0.94	1.15	0.09

Logistics infrastructure
This construct was measured by the density of several infrastructure components. To cover the relevant modes in Austria, trucking and railway networks were considered as well as connections to those networks. Moreover, logistics service providers were included, counting the number of subsidiaries, located in the region. The length of highways with classification "E" (international E-road network by the United Nations Economic Commission for Europe – UNECE) and the density of the railway network gave the basis of this construct. To account for the accessibility of the infrastructure, the number of multimodal hubs was included. All four items were divided by the area of the respective region to obtain the density value.

Attractiveness for business investment
The density of companies per region measured this construct, together with the price of properties and a commuter's index. The price of properties was calculated by averaging the price for each municipality. This average was weighted by the area of permanent settlement of each municipality. The commuter's index was calculated by dividing the number of employees working in that region by the number of employees living in that region. This index is bigger than one, if more people commute into that region than out of the region and smaller than one otherwise.

Knowledge infrastructure
The number of educational institutes and the number of centers of technology constitute the knowledge infrastructure. Those centers are associations, that support the usage of new technologies of local companies and therefore, contribute to the increase of practically used knowledge.

Regional GDP
The regional GDP per capita was used as the measure of regional economic wealth in this study.

3.3 Data analysis
Partial Least Squares– Structural Equation Modeling (PLS-SEM) was used to analyze the data. We rigorously followed Nitzl and Chin (2017) and Hair et al. (2017), both of whom provide valuable discussions on the different aspects of PLS-SEM.

PLS-SEM is a flexible and holistic approach, that allows 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 exploratory analysis and when the sample size is small (Reinartz et al., 2009). Technically the goal of PLS is to maximize the explained variance of the dependent variables (Tenenhaus et al., 2005); for further details see Chin et al. (2006).

The entire population of our research is constrained to 35, the total number of regions in Austria. Therefore, we include the entire population in our data analysis. Because of the limited population size, the 10 times rule (Barclay et al., 1995) that says the sample size should be at least ten times the number of maximum arrows pointing from items to a formative construct or, if higher, the maximum number of arrows pointing from a construct to another construct is not met. In our case, the rule leads to $n \geq 40$, since four is the largest number of formative indicators used to measure a construct and the largest number of arrows in the inner model, pointing at a construct is less than four. While reducing the items measuring the formative construct of logistics infrastructure would reduce the recommended sample size to 30, a formative construct should cover all relevant aspects. A complete operationalization of constructs was considered more important in this study.

Vienna is the biggest city of Austria and accounts for 20% of companies and 21% of population. It is also the eleventh biggest city in Europe (continent). The second largest city of Austria is Graz and does not feature even in the 100 largest cities of Europe. In fact, it would take the next five NUTS 3 regions to make up the regional GDP equivalent to that of Vienna. Therefore, we conclude that Vienna represents an outlier in the set of NUTS 3 regions of Austria. As suggested by Hair et al. (2017), we excluded Vienna in the analysis, which resulted in a much better fit and a sample size of 34.

Two of the constructs of the model proposed above are suitable for a formative measurement, because the items related to those constructs are different aspects of the constructs and therefore sum up to build the construct. Those are logistics infrastructure and knowledge infrastructure. The attractiveness construct was the only one measured reflectively. This is because every single item, that was used for this construct, reflects the consequences of the construct (Hair et al., 2017).

The previous paragraphs provide the basis for the decision to use variance- based SEM. The low sample size of 34 regions and the mainly formative measurement are the key arguments. In addition, the complexity of the model is an argument for PLS-SEM. The complexity of the model in this paper lies in the middle of the field having four constructs with 10 items. Moreover, the goal of the analysis is to predict the key driver constructs, which also is recommended with PLS-SEM.

We used SmartPLS-Software Version 3 to calculate the model and evaluate the hypotheses (Ringle et al., 2015). To examine the construct measurements, we chose the no sign change option with 500 bootstraps and the bias-corrected bootstrapping method. This procedure allows determining the significance of the outer loadings, weights and path coefficients of the model. Since the data is not assumed to be normally distributed, the usual significance test as in any regression analysis does not work (Hair et al., 2017). Referring to multicollinearity, the variance inflation factor (VIF) was below five for all items, where five is the critical value (Hair et al., 2011).

3.4 Evaluation of the reflective measurement (attractiveness)
Following Hair et al. (2017), we began by evaluating the reflective construct by assessing the outer loadings of the items. As can be seen in Table 3, the outer loadings for all items are significant, i.e.

the p-value is very close to zero, indicating item reliability. However, the outer loading for the commuters' index is below 0.7, which is not recommended. For such cases, Hair et al. (2017) suggest considering composite reliability and Average Variance Extracted (AVE). A Composite Reliability value of 0.830 and AVE of 0.625 are good, therefore, the item was retained. In addition, convergent validity is given, which can be seen from the AVE. Finally, the Heterotrait-Monotrait Ratio (Henseler et al. 2015) was used to establish discriminant validity. The value of 0.731 is smaller than 0.85 and therefore accepted.

3.5 Evaluation of the formative measurements

Since formative measures do not necessarily covary, other criteria should be used to assess those measurement models (Hair et al., 2017). To assess content validity, all facets of the construct must be captured. This was done by a literature review (Arvis et al., 2016; Ghemawat & Altman, 2016; Schwab et al., 2017) and by considering the input of 70 participants who attended workshops in Austria.

The outer loadings were all significant, indicating convergent validity. Their p-values were less than or equal to 0.01 except for the number of educational institutes (< 0.05) and density of railway networks (< 0.1). We kept the latter two items as explained below.

Finally, we establish the significance and the relevance of the items. Table 2 shows significance of outer weights only for the item density of centers of technology. This outer loading gives the relative importance of the item. Hence, the other items - educational institutes, length of European highways, density of hubs and density of logistics service providers - are not important in relative terms, but are important in absolute terms, since their outer loadings are greater than 0.5 (see Table 3) and therefore we keep them.

The outer loading for length of rail network is below 0.5, which is not sufficient to keep this item. However, since its loading is significant, it was retained.

Table 2. Evaluation of the Construct Measurements: Outer Weights

Measurement of items for constructs [a]	Original Sample Mean [b]	Bootstrap Sample Mean [c]	Bootstrap confidence interval (2.5% - 97.5%)		Standard Deviation	T Statistics	P-Values
Density of centers of technology -> knowledge infrastructure	0.918	0.858	0.067	1.211	0.275	3.339	0.001***
Number of educational institutes -> knowledge infrastructure	0.163	0.045	-0.595	0.960	0.359	0.454	0.650
Commuters index <- attractiveness for business investment	0.346	0.376	0.194	0.642	0.115	3.024	0.003***
Density of companies <- attractiveness for business investment	0.525	0.501	0.380	0.686	0.085	6.171	0.000***
Price of property <- attractiveness for business investment	0.378	0.366	0.158	0.479	0.088	4.301	0.000***
Density of highways with class. 'E' -> logistics infrastructure	0.354	0.229	-0.342	0.588	0. 245	1.444	0.149
Density of rail network -> logistics infrastructure	-0.226	-0.175	-0.651	0.282	0.240	0.940	0.347
Density of multimodal hubs -> logistics infrastructure	0.643	0.595	-0.345	1.171	0.399	1.611	0.108

Density of logistics service providers -> logistics infrastructure	0.353	0.405	-0.321	1.342	0.430	0.821	0.412

a: '->' means, that the measurement is formative; '<-' means, that the measurement is reflective
b: Original sample is without bootstrapping
c: Bootstrap sample means are used to calculate p-values
*** means significance with significance level of 1%
** means significance with significance level of 5%
* means significance with significance level of 10%

Table 3. Evaluation of the Construct Measurements: Outer Loadings

Measurement of items for constructs [a]	Original Sample Mean [b]	Bootstrap Sample Mean [c]	Bootstrap confidence interval (2.5% - 97.5%)		Standard Deviation	T Statistics	P-Values
Density of centers of technology -> knowledge infrastructure	0.989	0.928	0.404	1.000	0.162	6.114	0.000***
Number of educational institutes -> knowledge infrastructure	0.563	0.565	-0.049	0.983	0.278	2.028	0.043**
Commuters index <- attractiveness for business investment	0.621	0.648	0.384	0.817	0.123	5.029	0.000***
Density of companies <- attractiveness for business investment	0.907	0.886	0.720	0.965	0.102	8.848	0.000***
Price of property <- attractiveness for business investment	0.818	0.781	0.380	0.935	0.159	5.154	0.000***
Density of highways with class. 'E' -> logistics infrastructure	0.671	0.595	-0.156	0.886	0.243	2.767	0.006***
Density of rail network -> logistics infrastructure	0.315	0.289	-0.106	0.612	0.186	1.689	0.091*
Density of multimodal hubs -> logistics infrastructure	0.916	0.882	0.642	0.993	0.110	8.343	0.000***
Density of logistics service providers -> logistics infrastructure	0.693	0.672	0.083	0.964	0.243	2.849	0.004***

a: '->' means, that the measurement is formative; '<-' means, that the measurement is reflective
b: Original sample is without bootstrapping
c: Bootstrap sample means are used to calculate p-values
*** means significance with significance level of 1%
** means significance with significance level of 5%
* means significance with significance level of 10%

4. Findings

4.1 Hypothesis evaluation

The relationships between the constructs form the inner model, the path coefficients and t-values from the bootstrapping can be seen in Figure 4. The path coefficients of three relationships are significant; namely, H1, H3 and H4 are supported (Table 4). The coefficients of determination (denoted by R^2) show the explanatory power of the model (Table 5). The value of 0.447 for attractiveness is the amount of variance (in the construct of attractiveness) that is explained by its predicting constructs, logistics and knowledge infrastructure. The value of 0.487 for logistics infrastructure is moderate, implying that knowledge infrastructure is not the only factor on which logistics infrastructure depends. The value of 0.308 for the regional GDP is somewhat weak, but not surprising, since the regional GDP depends on several other factors than infrastructure. The relative effects of the constructs on the respective endogenous constructs (denoted by f^2) are given in Table 6. The effects of attractiveness on regional GDP of 0.444, knowledge on logistics infrastructure of 0.948 and logistics infrastructure on attractiveness of 0.357 are large, while the effect of knowledge infrastructure on attractiveness of 0.004 is small. This gives evidence to reject H2.

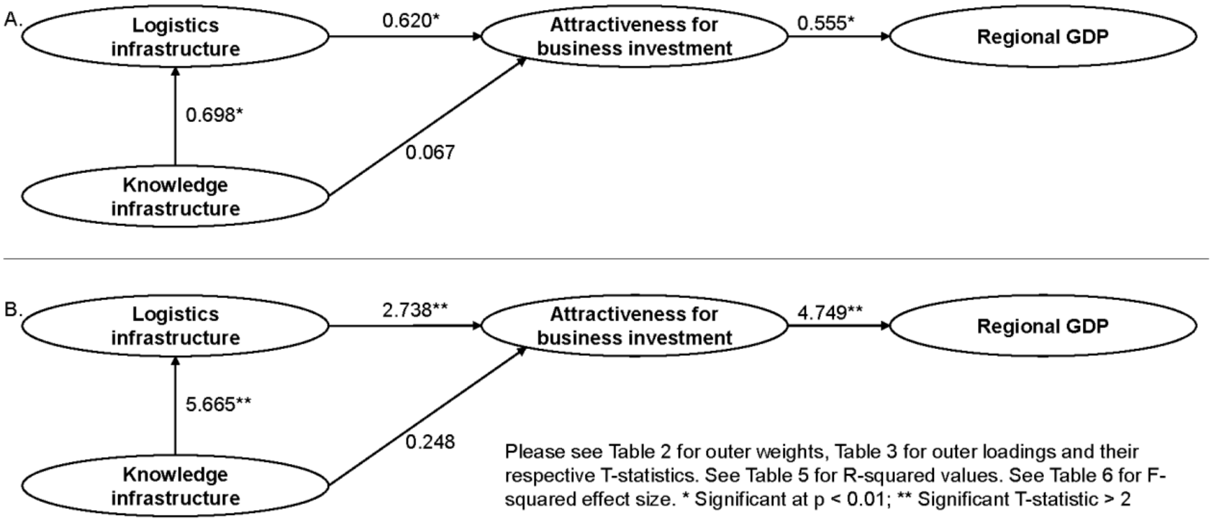

Figure 4. Estimated Model with Significance Information of the Effects (A: Results of inner model evaluation: direct effects, B: Results of the bootstrapping, T-statistics)

Table 4. Significance Values of the Inner Model: Direct Effects

Path Coefficients – Direct Effects							
From construct -> to construct	Original Sample	Sample Mean	Bootstrap confidence interval (2.5% - 97.5%)		Standard Deviation	T Statistics	P-Values
H1: Knowledge infrastructure -> logistics infrastructure	0.698	0.720	0.422	0.890	0.123	5.665	0,000***
H2: Knowledge infrastructure -> attractiveness for business investment	0.067	0.008	-0.536	0.554	0.272	0.248	0.804
H3: Logistics infrastructure -> attractiveness for business investment	0.620	0.691	0.171	1.088	0.226	2.738	0.006***
H4: Attractiveness for business investment -> regional GDP	0.555	0.576	0.322	0.774	0.117	4.749	0.000***

*** means significance with significance level of 1%
** means significance with significance level of 5%
* means significance with significance level of 10%

Table 5. Coefficients of Determination

Variable	R Square	R Square Adjusted
Attractiveness for business investment	0.447	0.411
Regional GDP	0.308	0.286
Logistics infrastructure	0.487	0.470

Table 6. f^2 Effect Size of the Relations Between the Constructs

f^2 effect size of the relations

To variable / From variable	Attractiveness for business investment	Regional GDP	Logistics infrastructure
Attractiveness for business investment		0.444	
Knowledge Infrastructure	0.004		0.948
Logistics infrastructure	0.357		

4.2 Discussion

Mediation:

The model suggests that the effect of knowledge infrastructure on regional GDP is mediated by logistics infrastructure and attractiveness for business investment. Therefore, it can be seen as a model of serial-multiple mediation (Hayes, 2018). However, we separately tested the mediation effects based on the method proposed by Baron and Kenny (1986). The mediating role of logistics infrastructure in the relation of knowledge to attractiveness was problematic, because of the insignificant effect of knowledge on attractiveness. According to McKinnon et al. (2007) the mediation can still be valid. The mediation of attractiveness in the relation of logistics infrastructure to regional GDP showed a classical full mediation effect.

The three indirect effects were found as given in Table 7. First, the indirect effect from knowledge infrastructure on attractiveness with logistics infrastructure as a mediator showed a significant effect with size 0.432 (p-value 0.027). Second, the indirect effects of logistics infrastructure on regional GDP with attractiveness as a mediator gave a significant effect of size of 0.344 (p-value 0.041). Third, the indirect effect of knowledge infrastructure on regional GDP, mediated of logistics and attractiveness was also significant with effect size 0.240 (p-value 0.087). Overall, the analysis suggests the mediating role of logistics infrastructure across multiple relationships.

Table 7. Significance Values of the Inner Model: Indirect Effects

Specific Indirect Effects	Original Sample	Sample Mean	Confidence interval from bootstrapping 2.5% - 97.5%		Standard Deviatio n	T Statistics	P-Values
Knowledge infrastructure -> logistics infrastructure -> attractiveness for business investment	0.432	0.496	0.133	0.889	0.195	2.219	0.027**
Knowledge infrastructure -> attractiveness for business investment ->	0.037	-0.001	-0.330	0.338	0.161	0.232	0.816

regional GDP							
Logistics infrastructure -> attractiveness for business investment -> regional GDP	0.344	0.402	0.095	0.740	0.168	2.042	0.041**
Knowledge infrastructure -> logistics infrastructure -> attractiveness for business investment -> regional GDP	0.240	0.291	0.057	0.592	0.140	1.715	0.087*

*** means significance with significance level of 1%
** means significance with significance level of 5%
* means significance with significance level of 10%

Relative and absolute importance of items:
Within logistics infrastructure, the items with the highest relative importance were density of hubs, followed by density of European highways and density of logistics service providers (weights of 0.918, 0.354, and 0.353 respectively). The items with highest absolute importance was density of hubs, followed by density of logistics service providers and density of European highways (loadings of 0.916, 0.693, and 0.671 respectively). Overall, density of hubs is the most important.

Within knowledge infrastructure, the item with the highest relative importance was the density of centers of technology (weight of 0.918), whereas the item "number of educational institutes" had a weight of 0.163. The items with highest absolute importance was the density of centers of technology (loading of 0.989), whereas the item "number of educational institutes" had a loading of 0.563. Within attractiveness of a region, the most important items were the density of companies and the average price of properties (with loadings of 0.907 and 0.818). The commuters index had a loading of 0.621. Overall, density of centers of technology is the most important.

One interpretation of the result is that managers in areas with several logistics hubs in close proximity allows them to choose the right transport mode and having a large number of logistics service providers at hand (i.e., density of logistics service providers) allows a manager access to the required competence. A large number of service providers provides access to different types of services at a competitive price. A high density of centers of technology provides access to latest technologies and innovations. It also attracts other technology companies and provides opportunities for collaboration with technology companies. A high density of companies provides access to complementary partners.

Importance performance analysis:
We conducted an importance performance analysis (Ringle & Sarstedt, 2016) to provide a roadmap to policymakers for prioritizing items for increasing the regional GDP. Figure 5(a) shows the comparison of importance and performance of each construct on the left side and Figure 5(b) of each item on the right side. Regional GDP is the target variable. Attractiveness has high importance and performance, while knowledge and logistics have low importance and performance. Three insights can be drawn from further analysis. First, four items have low performance at high importance, namely density of multimodal hubs, density of centers of technology, density of companies and price of properties. Policy makers may consider focusing on increasing the performance of these four items as it may impact the regional GDP. Second, policy makers may consider prioritizing investment in multimodal hubs over highways and service providers. Third, with respect to knowledge, new centers of technology seem to make a greater difference to (i.e., show higher correlations with) GDP than new educational institutes.

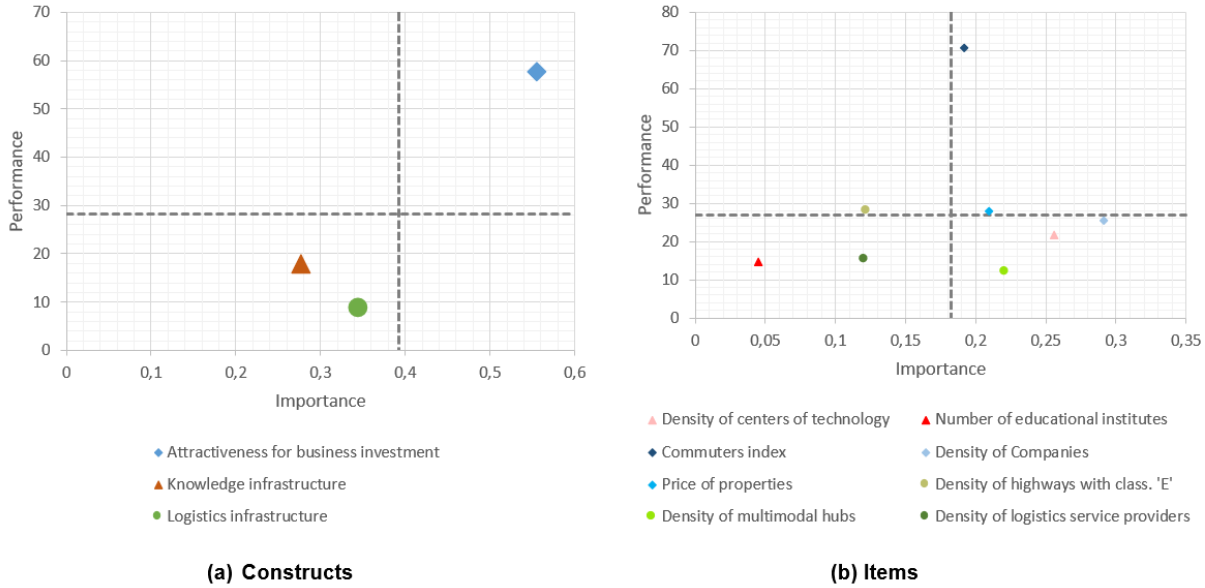

Figure 5. *Importance-Performance Analysis (for a. constructs, and b. items)*

Post hoc analysis:
We also tested for the impact of interaction between knowledge infrastructure and logistics infrastructure as well as direct effects from knowledge infrastructure to GDP, logistics infrastructure to GDP, and both logistics infrastructure and knowledge infrastructure to GDP. None of the relationships were significant lending credence to the fact that the relationship between knowledge infrastructure and the regional GDP is indeed mediated by logistics infrastructure and the attractiveness for business investment. In other words, only the availability of knowledge in an area does not drive regional GDP; having the right infrastructure is critical.

Discussion of excluded items:
We conducted additional analysis on items that were excluded during Step 4 of Figure 2. We did an exploratory factor analysis to further investigate the items that were excluded due to reasons such as multi-collinearity or lack of fit with a construct. For example, the density of navigable courses of river and the density of river ports loaded on one factor. On further exploration, it was discovered that navigable course exists only for the Danube river. Consequently, only a few regions have positive values for those two items while others have no way to directly benefit from inland waterway shipping.

Another example is related to density of population. Initially we placed high school rate under knowledge infrastructure and density of road network under logistics infrastructure. Our analysis revealed that the two items are highly correlated to density of population. These two factors were representing the density of people living in the region and not the business activities or the logistics infrastructure in the region. Further, density of population was initially included under attractiveness of the region but was not significant. Therefore, the three items ((high school completion rate, the density of the road network including small alleys, and density of population) were excluded.

5. Implications and limitations

This research presents a theoretical model (Figure 1) to establish and test relationships between logistics infrastructure, economic foundation for logistics, and the regional GDP. The results provide support for positive relationship between logistics infrastructure and the regional GDP, which is mediated by attractiveness of regions for business investment. While prior research has suggested these relationships at the country level (Arvis et al., 2016; Ghemawat & Altman, 2016; Schwab et al., 2017), this research provides an empirical test in a regional context.

Our research provides support for extant research and extends it. D'Aleo and Sergi (2017) tested hypotheses involving competitiveness, logistics and economic growth and found that competitiveness measured by the GCI is positively correlated with 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. Our research provides evidence that knowledge infrastructure is positively associated with logistics infrastructure which in turn is positively associated with business location attractiveness and consequently with regional GDP. This is the first study to provide rigorous, comprehensive empirical evidence of the logistics-related determinants of GDP at a regional level.

In the initial stages of this research, 73 indicators were identified. Through a rigorous process of elimination, the 10 items most critical to influencing regional GDP via the mediating role of attractiveness of a location for businesses were identified. This research directly fed into the development of Austrian Logistics Indicator (ALI). The ALI was developed by the home institution of two of the researchers and the Austrian Ministry of Transport, Innovation and Technology. ALI relies heavily on the indicators identified in this research. The master list of 73 indicators as well as shortlist of 10 items provides an actionable list for policy makers. It is used by the Austrian ministry to highlight top-logistics regions and identify those with improvement potential. It provides valuable information to justify future investments from ministries and local authorities. The next update of the numbers as well as the survey was planned for spring of 2020 but was delayed due to the COVID-19 pandemic.

This research establishes the link between logistics-related infrastructure and regional GDP thereby providing insights to managers as they persuade policy makers to make investments in most impactful infrastructural components. For example, companies in top-logistics regions in Austria use the ALI information to persuade multiple funding agencies to strengthen the top regions stronger to enable them to become EU-wide competitive logistics hubs whereas those in weaker logistics regions use the indicators to request additional funding to improve their regional infrastructure.

From a political point of view, this research promotes fact-based decision making. The entire procedure of selection and item calculation is available to the public. Lack of such transparency may raise concerns that the certain politicians or parties prefer logistics infrastructure projects and therefore allocate more resources to such projects in states governed by representatives from the same party. With the model developed in this research, decision making is based on publicly available and trusted data sources and consequently gets stronger support for logistics infrastructure related decisions from public and politicians. Investment in infrastructure has two sides. On one hand, macro-level view suggests that public investment in infrastructure leads to an improvement of efficiency and profitability in the private economy (Aschauer, 1989). 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 et al., 2009). This research helps to reconcile the two views by providing a model 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, using correlations between different constructs as a guide, the model 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.

Austria represents only one type of circumstances present in Europe. There are bigger countries and many with seaports, which have very different conditions for logistics performance. Since the data covers Austria, the findings and indicators are limited to Austria. However, future research can use this research as a template (see Figure 2) and extend the model to other countries and incorporate new indicators, for example, seaports. It is also important to note that GDP is affected by many different indicators, not only infrastructure. In our research, we focus on logistics-related determinants of regional GDP. Further, we could have inadvertently excluded variables that influence both the included determinants and GDP. Future research could incorporate both logistics-related and non-logistics related determinants of GDP as well as variables that impact logistics and knowledge infrastructure.

We argue and provide evidence that knowledge infrastructure is associated with logistics infrastructure which in turn is associated with business location attractiveness and consequently with regional GDP. While the model, constructs, and items were vetted by several knowledgeable stakeholders, it is plausible that the observed correlations are due to reverse effects. For example, it can be argued that more investments in infrastructure are made in economically-thriving regions. Future research could use longitudinal data to further understand these relationships.

Finally, the COVID-19 economic downturn may have impacted the regional GDP numbers. It would be interesting to study how logistics and knowledge infrastructure impacted GDP relative to the 'normal' economy numbers.

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Appendix A

	Item	Description	Item source	Data source	Remark
	Logistics Infrastructure				
1	Average size of existing properties for logistics	-	IIS-Fraunhofer	Fraunhofer - research institute	High correlation with items in Logistics and Knowledge. Excluded because other items are included.
	Number of logistic service providers	-	IIS-Fraunhofer	WKO****	Used in "Density of logistics service providers"
2	Density of logistic service providers	Number of logistics service providers per squared kilometer	IIS-Fraunhofer	WKO****	Included
3	Density of the railway network	Length of railway network in kilometers per squared kilometer	IIS-Fraunhofer	GIP (Graph Integration Platform)	Included
	Length of the railway network	Length in kilometers of street network of any classification	IIS-Fraunhofer	GIP (Graph Integration Platform)	Used in "Density of the railway network" calculation
4	Density of the highway network	Length of highways in kilometers per squared kilometer	IIS-Fraunhofer	GIP (Graph Integration Platform)	Eliminated for insignificant loading
	Length of highways with classification 'E'	Length in kilometers of street network with classification "European street"	IIS-Fraunhofer	UNECE	Used in "Density of highways with classification 'E'" calculation
	Number of airports	-	IIS-Fraunhofer	Investigation of the authors	Not considered because of very few (0-1) number of airports per region
5	Number of multimodal hubs	Multimodal hubs include trucking and rail. Some include inland vessel shipping	IIS-Fraunhofer	Ministry of transport in Austria	Used in "Density of multimodal hubs" calculation
6	Number of railway-terminals	-	IIS-Fraunhofer	Ministry of transport in Austria	Correlates highly with "Length of railway network". Excluded because other item is included.
7	Length of pipelines	Length in kilometers of pipelines	IIS-Fraunhofer	OMV AG	Rivers/waterways and pipelines are not significant. So, all items related to these two were eliminated.
8	Length of the rivers, where goods can be shipped	Length in kilometers of river that are used to ship goods	IIS-Fraunhofer	google.maps	Rivers/waterways and pipelines are not significant. So, all items related to these two were eliminated.
	Number of sea- or riverports	Only inland riverports since Austria is landlocked	IIS-Fraunhofer	Investigation of the authors	Not considered because of very few (0-4) number of ports per region
	Knowledge Infrastructure				
9	Educational institutes for logistics	Vocational schools, universities, institutes	Workshop, conducted by the authors	Verein Netzwerk Logistik	Included
10	Quality of tertiary institutions	Average ranking of universities and FHs	IIS-Fraunhofer	THE and Industrie-magazin***	Eliminated for insignificant loading

		(university of applied sciences) in the region			
11	Centers of technology	Number of technology centers, or business incubators in the region	The Global Competi-tiveness Report-WEF*	Investigation of the authors	
	Attractiveness of a region				
12	Average price for potential properties for logistics	Price of industrial building land	IIS-Fraunhofer	IMMOUnited GmbH	Included
13	Commuter into the region	Number of people that commute on a regular base	DHL-Connectivity Index**	Statistics Austria	Used in "Commuter-Index" calculation
	Commuters out of the region	Number of people that commute on a regular base	DHL-Connectivity Index**	Statistics Austria	Used in "Commuter-Index" calculation
	Commuters within the region	Number of people that commute on a regular base	DHL-Connectivity Index**	Statistics Austria	Used in "Commuter-Index" calculation
14	Density of companies per area of permanent settlement	Number of companies per squared kilometer	Workshop, conducted by the authors	WKO****	Included
	GDP				
	Residential population	Population per region	DHL-Connectivity Index; IIS-Fraunhofer	Statistics Austria	Used in multiple calculations but not an item by itself
15	Regional GDP	-	Global Resilience Index-FM Global; The Global Competi-tiveness Report-WEF*	Statistics Austria	Included

* World Economic Forum
** And the McKinsey Connectedness Index
*** Times Higher Education and an industrial journal
**** The Austrian federal economic chamber