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Identifying a Country's Freight Transport-Intensive Economic Sectors and Their Logistics Emissions—Method Development and Exemplary Evaluation with Austria

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Abstract: It is unequivocal that global greenhouse gas emissions must be reduced drastically. One opportunity to quickly achieve deep emission reductions is by investigating the largest emitters first. This can be based on countries but also on the underlying sectors of local economies. Focusing on the latter, the transport and industry sectors stand out, as well as their overlap, which is reflected in the emissions from freight transport. To enable legislators and researchers to focus on the major emitters in freight transport and to develop tailored sectoral measures, we present a method to identify the transport-intensive sectors of a country. A two-part approach thereby makes it possible to identify these sectors and their value chains and to analyze the different emission structures of companies between the sectors. This suggests the relevance of decarbonizing transport from a company's perspective and helps to understand the entrenched situation. Finally, the methodology is applied to the Austrian transport industry as an example to demonstrate its applicability. As applied research in this area has lagged somewhat, our results can provide managers in transport-intensive economic sectors with new motivation to decarbonize logistics, as well as guide policymakers and researchers on which sectors to focus first.

Keywords: greenhouse gas emissions; climate change; transportation; logistics; transport-intensive sectors; transport-intensive value chain; reporting

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1. Introduction

With the contribution of the first working group on the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the harmonization of thousands of sound scientific findings enhanced the understanding of the physical science basis of climate change and established confidence that the warming of the earth's surface temperature can be attributed to anthropogenic greenhouse gas (GHG) emissions [1]. Following this report, the second IPCC working group deals with consequences arising from this climate change and points to nothing less than a serious climate crisis, including extreme weather events, climate-caused refugee movements, biodiversity loss, and mental health challenges if GHG emissions are not profoundly reduced in the near-term [2]. Those findings, again, highlight the need to reduce emissions significantly as soon as possible. To do so, a prominent strategy is a top-down approach, focusing on the top emitters first and implementing carbon-neutral or carbon-free practices among them. This can be performed on the country level, concentrating, first, on the nations that emit most of the emissions. Having a look at the top-emitting countries, China has been leading this list since about 2006, when it passed the United States of America [3]. However, this perspective on prioritizing decarbonization poses some problems. First, it enters the discussion of emissions accountability since "China emitted considerable amounts of carbon dioxide on behalf of foreign consumers in the years from 2000 to 2014" [4]. Thus, the question arises of how to deal with and allocate emissions embodied in global trade [5], resulting in a dilemma between "production-based" and "consumption-based" responsibility [6]. Additionally, secondly, new estimations and datasets show that ranking by country no longer reflects the real situation since the inequality of income inside countries is overwhelming, and the top 10% of the earth's population emits 48% of the global GHG emissions, while the bottom half of the population emits 12% [7]. Therefore, the concentration on the top-emitting countries does not seem to be appropriate anymore.

Another perspective to focus on top emitters first is the division of global emissions by economic sectors. Although small differences in the concrete figures among different reports exist, the energy sector is undoubtedly the top emitter, contributing 25 to 42% of the global anthropogenic GHG emissions [8–10]. Subsequently, emissions from the industrial sector amount to 21–23% and from the transport sector 14–23% [9,10], awarding them silver and bronze in the ranking of top-emitting economic sectors, respectively. The emissions from industry will further rise when indirect emissions are accounted to this sector. Following the Greenhouse Gas Protocol's logic, not only direct emissions created by production processes, so-called "Scope 1" emissions, are to be allocated to the industry, but also indirect emissions that emerge in the generation of energy used by the companies ("Scope 2"), as well as emissions from the companies' value chains ("Scope 3") [11,12]. Considering also Scope 2 emissions, the emissions of the industrial sector increased by another 11% [10]. Similarly, certain emissions from the transport sector can be attributed to the industry—which are the up- and downstream Scope 3 emissions from transportation purchases. Those originate from the need of industrial companies to transport raw, auxiliary, and operating materials, as well as intermediate and end products [13], and are originally accounted for as freight transport emissions. In total, freight transport accounts for around 30% of the transport sectors' emissions [14], resulting in 4 and 7% of the worldwide GHG emissions. Accounting for those in the industrial sector leads to an increase in the industry's emissions by 4–7%, pushing it to the pole position of global GHG emitters. Although emission reduction initiatives in the Scope 1 manufacturing processes are slowly starting to take effect, measures in logistics that are mainly accounted for in Scope 3 do not yet reach their expected potential [15].

Therefore, current research should have a serious interest in examining more closely the emissions arising from the up-and downstream transportation activities of shippers. Splitting up the industry into smaller industrial sectors producing and handling specific goods allows for tightening the aforementioned top-down approach, focusing first on the sectors with the highest transportation demands and, thus, the highest emissions from transportation. Therefore, the structure of a country's freight transport system needs to be known so that macroeconomic decarbonization initiatives can be steered to have their effect first in transport-intensive sectors.

Whereas the extant literature on decarbonization measures in logistics exists [16], research on the transport-intensiveness of different sectors is scarce. Only a few articles dealing with this could be found when screening the pertinent literature on this topic. A survey aiming at transport-intensive industries in Sweden was sent to companies in nine different sectors, namely agriculture/forestry; chemical; food and drinks; manufacturing; manufacturing other; ore/metal; pulp, paper and paper articles; wholesale trade; and logistics service providers. The selection of those sectors is thereby argued by the statement that "the span of logistical demands in these industries covers a variety of requirements in terms of costs, flexibility, delivery time and quality" [17]. At least the selection of forest products can be validated by another study from a Scandinavian country, mentioning that about 14% of the tonne kilometers in the domestic freight transport of Norway originate from the forest sector [18]. Swiss authors elaborate on the transport-intensive sectors of Switzerland based on official statistics [19]. The primary industries identified were the chemical and plastics industry, metal industry, mechanical engineering, electrical and precision engineering, construction industry, food and beverage industry, and mineral oil industry. These were expanded to include the two cross-sectional sectors of retail and wholesale and waste and recycling. The authors thereby discuss their methodology in detail and combine economic data with transportation volumes. For China, economic data from the China Statistical Yearbook 2000 are used in [20] to derive the transport intensity of different sectors. Those are composed similarly to the Swiss but account for significantly more transportation services to the agricultural sector [20]. Although some other papers exist that use the term "transport-intensive" in some form [21,22], to the authors' surprise, no further papers could be found that define the term or elaborate on other countries' sectors. All in all, this leads to the assumption that the transport-intensive sectors differ country-wise, based on the unique composition and characteristics of economic activities in the countries, but that no general methodology to identify those sectors exists.

To close this gap, we develop a methodology on how to identify the transport-intensive sectors of a country generically. We base our method on the methodology used in the aforementioned Swiss study [19] and extend it with data and methods from the EcoTransIT World emission calculation tool [23]. In this way, we define a methodology that has minimum requirements for official statistics and, at the same time, is close to reality and thus finds applicability in as many countries as possible. For evaluation, we use Austria as an example because the country is comparable to Switzerland in terms of being a landlocked, middle-European, developed country, with a hilly surface and access to important European inland waterways.

Providing a methodology that identifies transport-intensive sectors allows researchers and policymakers to easily compare countries and provides an initial indication of which macroeconomic sectors to focus on first when aiming at emission reduction in freight transportation.

With this knowledge, legislators, for example, can develop sector-specific incentives to promote the implementation of decarbonization measures for a set of companies. To do this, however, it is essential to understand which companies operate in these sectors and how logistics emissions are relevant to them. Of particular interest is the share of logistics emissions in a company's total emissions, which determines how relevant the decarbonization of logistics is for the overall decarbonization efforts of the company. Manufacturing companies, e.g., are reported to perceive larger emission reduction potentials in their core operations than in logistics and therefore tend to focus on those areas first [24]. Little data on the numbers of companies' emissions attributable to logistics are presented in the literature [24]. Individual figures suggest that the share of emissions attributable to logistics among manufacturers is about 8% [25], having outliers such as the fashion industry accounting for up to 35% of the Corporate Carbon Footprint to logistics [26]. To provide a guideline on how to identify this share in a sound and comparable way, we extend our methodology by a second part. With this part, we aim to provide an answer to the question of what percentage of a transport-intensive company's total emissions is attributable to logistics and whether this share differs between the transport-intensive economic sectors. Again, we use Austria as an example to evaluate the methodology and analyze non-financial reports of Austrian companies that belong to the transport-intensive industry sectors.

Based on these considerations, the two overarching research questions of the focal paper were formulated and answered throughout the research:

- How to identify transport-intensive sectors of a country with minimal requirements to official statistics in a realistic manner?
- How to identify the percentage of a transport-intensive company's total emissions that are attributable to logistics and compare this share among the transport-intensive economic sectors?

The remainder of this paper is structured as follows: Section 2 presents the methodology and is split up into two subchapters, each describing the methodology used to answer one research question. Section 3 is similarly structured, presenting the results of the methodology. Section 4 discusses the results and Section 5 comprises a brief conclusion.

2. Research Methodology

As described in Section 1, we present a twofold methodological approach in this paper. First, a top-down analysis of transportation statistics reveals the transport-intensive sectors of the country under study. Second, a bottom-up approach enables the researchers to gain deeper insights into the structure of the identified sectors.

2.1. Transport-Intensive Economic Sectors

To identify a country's transport-intensive economic sectors, we adopt and modify a research approach taken by Swiss authors [19] aimed at understanding the Swiss freight transportation system. As discussed above, this study was selected as a methodological starting point because it is one of the few scientific publications in this field, and it ensures the comparability and verification of the results of the developed methodology.

The underlying data of the methodology and, thus, the starting point are official transport statistics of the country under study. From this, solely the transport volume in tons denoted as M, grouped according to the types of goods is used. We suggest using the goods classification defined in the classification system for transport statistics (NST 2007) on the division level and the modes of road freight, rail freight, as well as freight transported on inland waterways to cover all domestic modes of transport.

However, if only the mass of transported goods is used as an indicator of transport intensity, the picture is distorted because high-volume, low-density goods are neglected. The Swiss authors, therefore, use economic data of the sectors (value of goods, gross value added) as well as data on transport performance (tonne kilometers) to conclude the transported goods. However, since we strongly doubt the availability of these data in other countries and thus the generic applicability of the methodology, we have modified it at this point. To account for the influence of volume, we include an approach used by the EcoTransIT World emissions calculation tool [23] (p. 32). Therein, the transported mass M is adjusted by the average vehicle capacity utilization CU_{NC}, which depends on the goods category. Calculating $M_{adj} = \frac{M}{CU_{NC}}$ additionally includes the consideration of empty runs in the analysis. EcoTransIT was consulted due to its clear documentation and its broad acceptance in academia and practice. To consider different values for CU_{NC} across different NST divisions, cargo types are allocated to the goods in accordance with the description of the cargo types and examples provided in the EcoTransIT World methodology [23] (p. 31). If no logical allocation can be found, we suggest allocating the cargo type "average" to ensure comparability.

Having calculated M_{adj}, we order the goods descending by their respective M_{adj} and calculate the share of the total M_{adj} for each goods division. Then, the cumulative share of each NST division was computed to identify the goods that account for 80% of the total M_{adj}, following [19]. Thereby, the economies of transport-intensive goods are identified.

To map those goods to related economic sectors, we consult the description of the goods presented in the NST 2007 classification [27]. The goods are then mapped to those economic sectors that are producers, processors, or manufacturers of the goods. To ensure the comparability of economic sectors between countries, we recommend following the Classification of Economic Activities in the European Community, briefly called NACE [28]. This step results in the list of the economies' transport-intensive economic sectors.

For a more concise presentation of the results, we further cluster the sectors and formulate transport-intensive value chains based on supplier–demander relationships among the transport-intensive sectors.

In the last step, we discuss the limitations that we faced when applying the methodology and challenge our results against the existing literature on the topic.

The methodological approach is visually summarized in the first line of Figure 1.

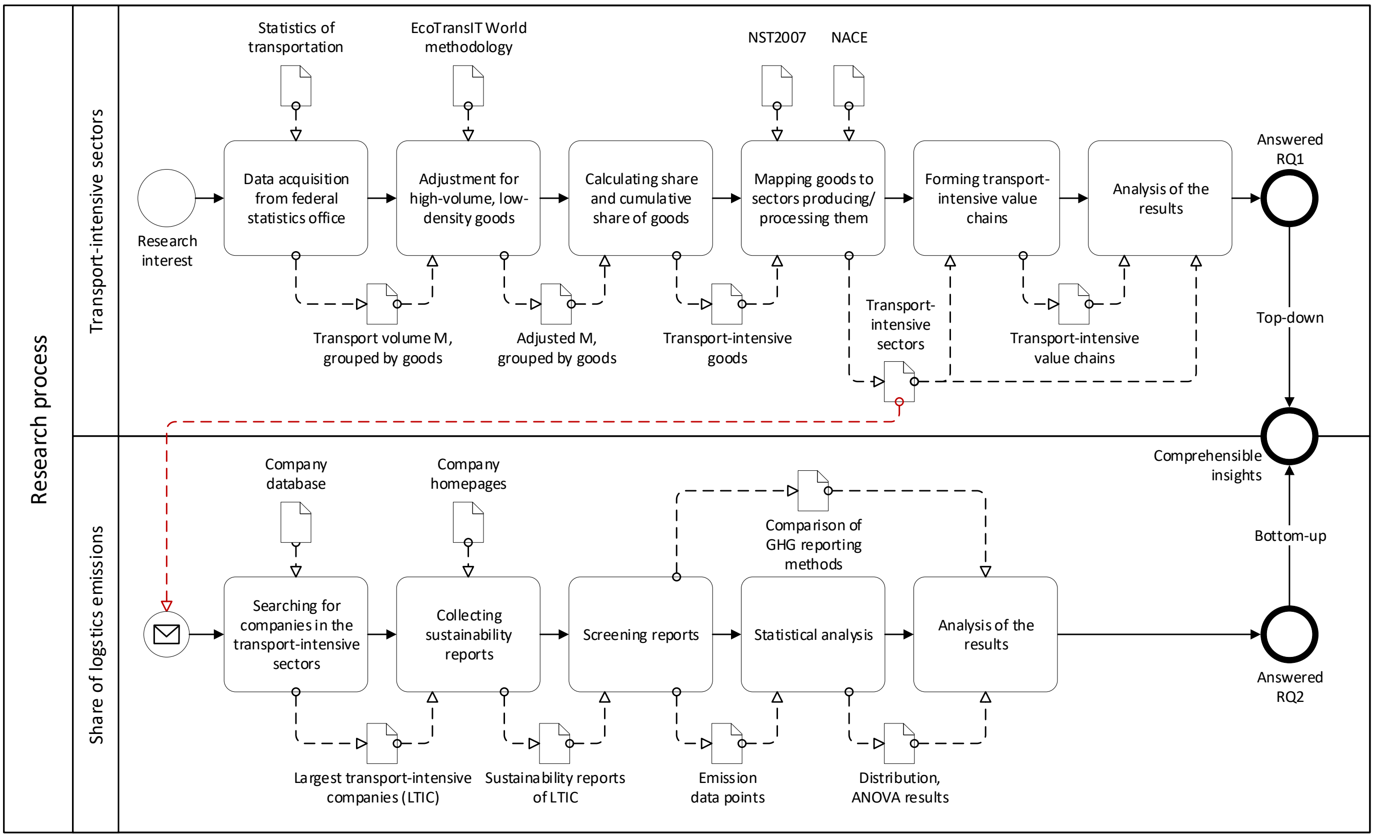

Figure 1. Research process.

2.2. Logisitcs Emissions in the Transport-Intensive Economic Sectors

To answer the second research question and identify the share of logistics emissions and sectoral differences, the transport-intensive economic sectors identified in the first part provide a starting point for a systematic search in a database that comprises company data for the country under study. Searching each of the sectors with predefined parameters filters the database according to the economic sector, number of employees, and turnover. To handle a high number of results, we propose to first select the top ten companies by turnover and then combine this with the top ten companies by the number of employees. This results in the set of the largest transport-intensive companies (LTIC).

Subsequently, as visualized in the second row of Figure 1, further desk research is conducted by analyzing the companies' homepages and trying to find published non-financial reports, which are referenced as Sustainability Reports (SR) in the further manuscript. All kinds of SR, no matter if they are compliant with specific standards such as the Global Reporting Initiative (GRI) or the Eco-Management and Audit Scheme (EMAS), are collected in this stage. If companies are part of a group and the group publishes an SR, the group SR is taken for the analysis. Therefore, companies of the same group are assigned the same SR, which lowers the sample size of the subsequent statistical analysis. We only consider SR, in which figures regarding the absolute GHG emissions in the timespan 2017–2020 are reported.

Screening the SR is accompanied by analyzing and comparing them regarding the method of emission reporting, the reported scopes, and the reported emission units. The main goal of this step is the extraction of data points from the reports, whereby one data point represents the emissions of one company in one year, which can be further split up into emission categories.

To make a generalized statement about the share of logistics emissions in the total emissions of transport-intensive companies, the distribution underlying the data is examined. We suggest doing this by fitting the data points with a Maximum Likelihood

Estimation to all 98 continuous distributions listed in scipy.stats [29] and check the Goodness of Fit by performing a Kolmogorov–Smirnov test. A commonly used distribution with an appropriate p-value (we suggest $\alpha = 0.05$) then describes the data points. Besides this distribution, the differences in emissions shares across the investigated value chains are examined in this phase. Therefore, the impact of the value chain a company is in on a company's share of logistics emissions is assessed by conducting a one-way ANOVA. This test shows if statistically significant differences across the transport-intensive value chains exist.

Similar to the first part of the methodology, limitations and comparisons to the similar literature are discussed in the last phase.

3. Evaluation of the Methodology with Austria

Austria was selected as an example because it is, first, comparable to Switzerland, as described above, and second, no data on the transport-intensive sectors are available yet.

3.1. Transport-Intensive Economic Sectors

After applying the methodology described in Section 2.1 to the Austrian transportation system, using statistics from the Austrian Federal Statistics Office [30] (p. 28) as a basis, the results in the selection of Austria's transport-intensive goods, as well as their respective business sectors, are listed in Table 1. The used statistics include domestic traffic, cross-border receipts, and cross-border dispatch but exclude transit traffic. The divisions 18 "grouped goods", 19 "unidentifiable goods", and goods that cannot be assigned to any division were removed during the application of the methodology because they account for less than 4% of Austrian transport volume. Note that the sum of all shares presented in Table 1. is not 100%, which is because we only present the transport-intensive economic sectors in this paper. The full list is provided in the supplementary material.

Table 1. Transport-intensive goods and their respective transport-intensive economic sectors in Austria, resulting from the developed methodology (source: own calculations based on [30] and mapped based on [28]).

NST 2007 Division		NACE Division		M_{adj}	Share
3	Metal ores and other mining and quarrying products; peat; uranium and thorium	B5	Mining of coal and lignite	245,533	21.66%
		B6	Extraction of crude petroleum and natural gas		
		B7	Mining of metal ores		
		B8	Quarrying of stone, sand, and clay		
4	Food products, beverages, and tobacco	C10	Manufacture of food products	145,236	12.81%
		C11	Manufacture of beverages		
		C12	Manufacture of tobacco products		
9	Other non-metallic mineral products	C23	Manufacture of other non-metallic mineral products	142,288	12.55%
10	Basic metals; fabricated metal products, except machinery and equipment	C24	Manufacture of basic metals	113,574	10.02%
		C25	Manufacture of fabricated metal products, except machinery and equipment		
1	Products of agriculture, hunting, and forestry; fish and other fishing products	A1	Crop and animal production, hunting, and related service activities	107,371	9.47%
		A2	Forestry and logging		
		A3	Fishing and aquaculture		

Table 1. *Cont.*

NST 2007 Division		NACE Division		M_{adj}	Share
6	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper, and paper products; printed matter and recorded media	C16	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	75,394	6.65%
		C17	Manufacture of paper and paper products		
14	Secondary raw materials; municipal wastes and other wastes	E38	Waste collection, treatment, and disposal activities; materials recovery	68,150	6.01%
12	Transport equipment	C29	Manufacture of motor vehicles, trailers and semi-trailers	43,905	3.87%
		C30	Manufacture of other transport equipment		

The most transport-intensive goods are, by far, metal ores and other quarrying products, peat, uranium, and thorium. This is a plausible finding because companies manufacturing those goods are, among others, suppliers for the metalworking industry (NACE divisions C24 and C25), which represents a significant economic sector in Austria, alone generating about 4.4% of the total revenue of Austrian companies [31]. Therefore, it is also understandable that these divisions, as demanders and further processors of transport-intensive goods, are also found among the transport-intensive industries. These supplier–demander pairs can be summarized as the Metal Value Chain (VC), as visualized in Figure 2. Non-metal mining and quarrying products that are extracted (B5 and B8) and further processed to non-metallic mineral products (C23) form the Mineral VC. Another supplier–demander pair can be found in the identified sectors, which is the agricultural sector (A1–A3) that manufactures and supplies input materials for the food and beverages industry (C10–C12), forming the Food VC. The same accounts for the manufacturing of products from wood (C16 and C17), forming the Wood VC. The manufacturing of motor vehicles, trailers, semi-trailers (C29), and other transport equipment (C30) is somewhat exceptional in this way because this sector is usually supplied by the Metal, Mineral, and sometimes Wood VCs. A cross-sectoral transport-intensive sector is the collection and processing of waste (E38), as this is necessary for all the value chains described.

Comparing our results to the Swiss study that was used as a methodological reference lead to the conclusion that the sectors do relate to a great amount but differ in some details. Astonishingly, the chemical industry is missing in the Austrian transport-intensive sectors. This might be due to the chemical industry being significantly smaller in Austria, as measured by the relative number of employees in the chemical industry (NACE division C20) to those in total manufacturing (NACE category C), which accounts for 2.86% and 4.3% in Austria and Switzerland, respectively [32,33]. Given the similarity of the two countries' freight transport systems and the logical arguments for the differences, we conclude that our methodology leads to valid findings of the transport-intensive economic sectors.

Three limitations that we faced when applying the methodology should be discussed. As already mentioned above, the first limitation is the neglect of tonne kilometers in the calculation due to scarce data, which underestimates the impact of high-volume, low-density goods. This drawback was addressed by including the mean capacity utilization adopted from EcoTransIT. One indication that this approach in calculating M_{adj} is valid is the inclusion of companies manufacturing transport equipment (NACE divisions 29 and 30) in the transport-intensive economic sectors after consideration of CU_{NC}. This sector ranked fourth in average revenue per company and fifth in average employees per company in Austria in 2019 [33], thus representing an important sector of the economy, but was not included in the transport-intensive sectors when only considering M. This is because the transportation demand for those goods is mainly driven by their volumetric properties and not their weight [23]. Nevertheless, another validity check should be performed as soon as more granular data on tonne kilometers traveled is available at the NST level. A second debatable point of the focal methodology is the allocation of goods to the sectors that manufacture or produce them. In this respect, only the transport of already-finished goods is considered. This makes sense for raw materials but may distort the picture for producers who are closer to the end customer, as their inbound transports are not accounted to them. This limitation was eased by considering the entire value chain, including supplier–demander pairs and thus causing these allocation discussions to be obsolete. The third limitation may be specific to the application of the methodology with the Austrian statistics because it is not entirely clear if the goods for which the transportation volumes were considered originate from Austria. Therefore, it is hard to logically argue that the companies from the identified transport-intensive sectors are located exclusively in Austria.

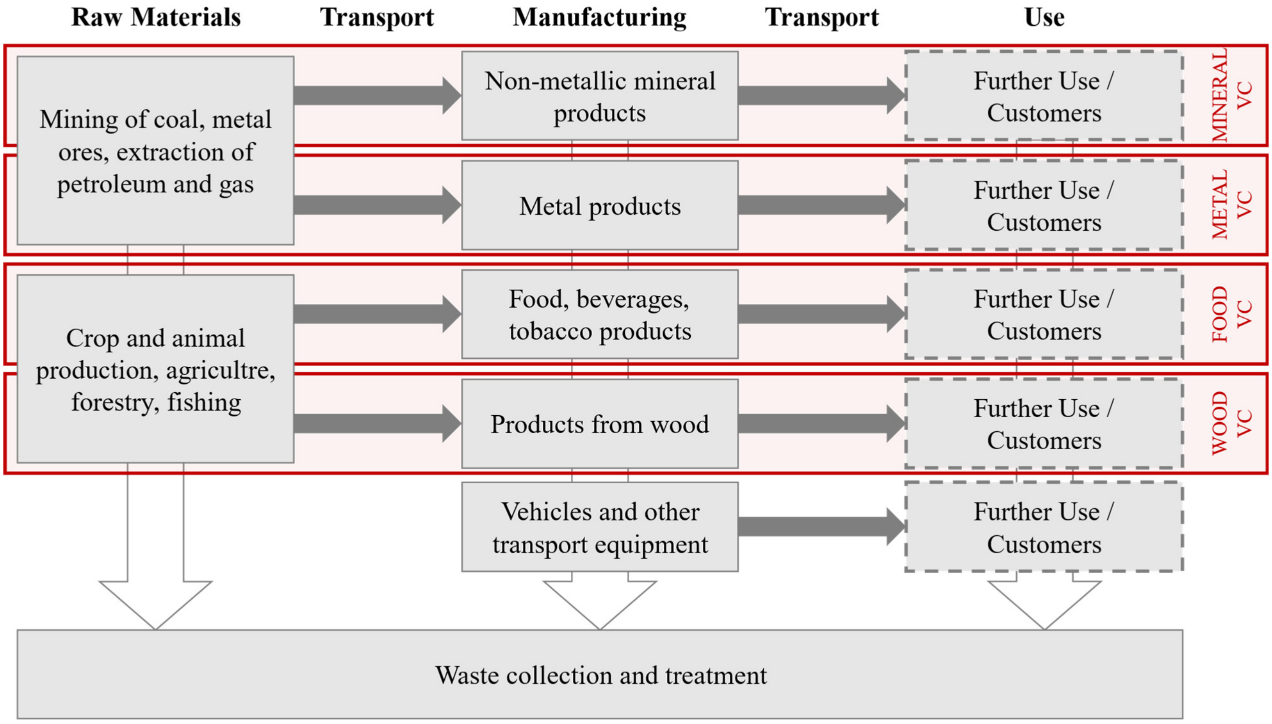

Figure 2. Visualization of the transport-intensive value chains in Austria.

3.2. Logistics Emissions in the Transport-Intensive Economic Sectors

3.2.1. Collecting Companies and Reports

To collect data on Austrian companies in the transport-intensive sectors, we use the Aurelia database [34]. Minimal values for the sorting parameters are a turnover of 10,000 EUR and ten employees. Except for NACE division B5, entries were found in all categories, thereby resulting in a total of 179 companies that, together, form the set of the LTIC in Austria.

For 108 of 179 companies (60.34%), no report could be found. For another eleven companies (6.15%), a report without figures on emissions could be found, and in the reports of five firms (2.79%), only specific emissions related to output or profit were reported. Thus, reports of 55 companies (30.73%) in the set of LTIC were considered. Since some companies belong to a parent group for which a central report is prepared, reports from a total of 38 business entities were analyzed.

3.2.2. Screening the Reports

All in all, we extracted 116 data points from the reports. Investigating the distribution of the data points over time on the left-hand side of Table 2 and Figure 3a, we see an inclination year by year, starting with 20 in 2017, rising to 29 in 2018, and reaching 33 and 34 in 2019 and 2020, respectively. This provides the first indication that although there has been a rise in emission reporting among companies in the considered period, saturation has been reached in the last two years. We observed most of the data points in the Wood and Food VCs. The existing data points were filtered once again, as only emission values that are further subdivided and for which logistics emissions are explicitly reported can be used to answer the research question. The remaining data points are shown on the right-hand side of Table 2 and Figure 3b.

Table 2. Distribution of data points over time and VC.

	All Data Points					Data Points Presenting Logistics Emissions				
	2017	2018	2019	2020	Total	2017	2018	2019	2020	Total
Food	8	8	7	8	31	3	3	2	5	13
Metal	2	4	4	4	14	1	1	1	2	5
Mineral	1	2	5	4	12	0	1	1	1	3
Other	1	2	2	2	7	0	0	0	0	0
Transport	1	4	6	7	18	1	1	1	2	5
Waste	2	3	3	3	11	2	3	3	3	11
Wood	5	6	6	6	23	1	1	2	2	6
Total	20	29	33	34	116	8	10	10	15	43

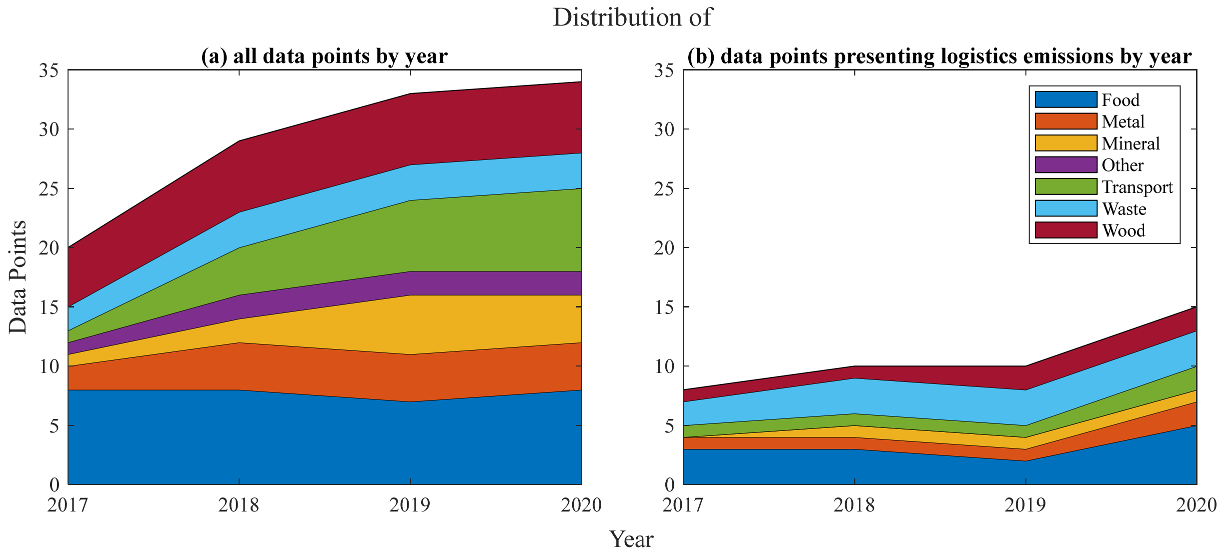

Figure 3. Number of data points over time and VC.

In total, only 43 of 116 data points (37.07%) separately present logistics emissions, but a rise in this share can be seen from 2019 to 2020, indicating a positive movement towards more solid logistics emission reporting. However, keeping in mind that the overall number of 116 data points was generated from reports of only 30.73% of companies in the set of LTIC, we can clearly state that reporting on logistics emissions is still in its infancy among the companies of the transport-intensive economic sectors in Austria, which is a call for action towards practitioners.

Investigating the reported emissions of logistics in more depth reveals another weakness in current reporting because the way these emissions are reported is extremely divergent. An overview of these ways of reporting is visualized in Table 3, employing a morphological box in descending order of detail, presenting each analyzed report together with its logistics emission categories. Thus, at the bottom row, the most detailed way of reporting is displayed. In there, the grey-colored boxes describe the different categories for which figures are presented in the SR. Only one company reports in the most detailed way, separately disclosing Scope 1, Scope 2, and Scope 3 emissions and further pointing out emissions from the transportation by vehicles that are owned by the companies (Scope 1 Logistics), as well as upstream and downstream transportation (Scope 3). Looking at the rows above the bottom one, companies start to aggregate their logistics emissions in different ways, i.e., summarizing all Scope 3 transportation emissions or even only reporting on emissions from logistics in general, but not describing what is meant in detail. All in all, this variety of ways in which emissions from logistics are reported leads to diminished meaningfulness of further analyses.

Table 3. Overview of the level of detail of reporting on logistics emissions in the analyzed SR.

Report(s)	Reporting on Logistics Emissions			Scope 1	Scope 2	Scope 3	Total Emissions
[35–38]	Transportation/Logistics in total						x
[39] [1]	Transportation/Logistics in total			x	x		
[40,41]	Scope 1 Log			x	x	x	
[42]	Scope 1 Log	Scope 3 Transport		x	x	x	
[43–45]		Scope 3 Transport		x	x	x	
[46]		Scope 3 Up		x	x	x	
[47]	Scope 1 Log	Scope 3 Up		x	x	x	
[48,49]		Scope 3 Up	Scope 3 Down	x	x	x	
[50]	Scope 1 Log	Scope 3 Up	Scope 3 Down	x	x	x	

[1] Although not specifically mentioned in the SR, logistics emissions from these SR were further considered to be Scope 1 emissions due to the absence of Scope 3 emission reporting.

3.2.3. Statistical Analysis

Due to the data describing different years and having different mean values over the observed years, we normalize the data by the mean value of the respective year $\tilde{x}_i = x_i/\overline{x}_i,\ i \in \{2017, 2018, 2019, 2022\}$ before the statistical analysis. Then, the data are fitted with a Maximum Likelihood Estimation to 98 continuous distributions listed in scipy.stats [29]. To check the Goodness of Fit, a Kolmogorov–Smirnov test is performed. The p-value leads to the rejection of 22 tested distributions ($\alpha = 0.05$), leaving 76 distributions not rejected. According to the residual sum of squares and the residual standard error (RSE), the three-parameter kappa distribution shows the best fit ($p = 0.9803,\ RSE = 0.0714$). However, when examining more common distributions, the log-normal distribution shows good results ($p = 0.8744,\ RSE = 0.0910$). The log-normal distribution was also shown to describe other data similarly well as the kappa distribution [51] and is suggested by different authors concerning emissions [52–56], but it is not generally observed [52]. Anyway, a modified version of the log-normal distribution, the power log-normal distribution, fits data even better ($p = 0.9132,\ RSE = 0.0857$), which is why we use it for further investigations. Figure 4 shows the probability density function (PDF), the cumulative distribution function (CDF), and the probability plot of the normalized empirical data $\tilde{x}_i$ and the fitted power log-normal distribution ($c = 176.69897614596493,\ \ s = 2.5642482494271484,\ \ location = -0.011826190254987191,\ \ scale = 669.729829463008$). Here, the unit length for the PDF representation of the theoretical distribution refers to the class width of the displayed histogram for better interpretability. The plots depict the close relation between the theoretical distribution and the empirical datapoints. This also shows the suitability of the distribution to represent the share of logistics emissions. The parameters and results of the Kolmogorov–Smirnov tests of all distributions are provided in the supplementary data.

Due to the limited sample size and the limited number of years considered, it is hardly possible to draw significant conclusions about the historical development of the logistics emission share. Nevertheless, to provide a first idea of the historical development of emission shares in the observed years, we present the share of total logistics emissions relative to the total emissions of the company using four box plots in Figure 5a. An enormous range of logistics emission shares is identified, thereby reaching from 1% to 95%. Although different interquartile ranges throughout the years, a similar median value of about 10% is identified in all years. The outlier on the upper end of each plot can be explained due to the type of business the company reporting these figures is doing—operating waste collection vehicles to collect waste from households and industrial customers. Thus, the main activity of this company is the transportation of waste and, therefore, the logistics emissions are correspondingly high. To avoid distortion of the results, this outlier is excluded from further analysis, leading to Table 4 and Figure 5b. In there, the mean share of logistics emissions relative to the total emissions $\overline{x}$ as well as their respective standard deviations (we use the standard deviation of a sample $s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2}$), which are evaluated by year and value chain.

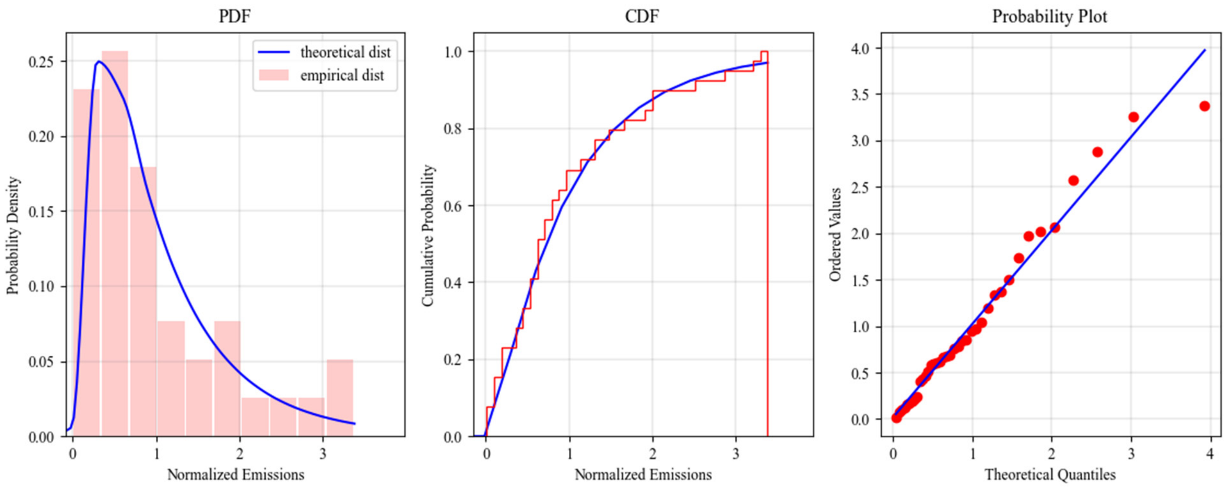

Figure 4. Representation of the fitted log-normal distribution compared with the empirical distribution.

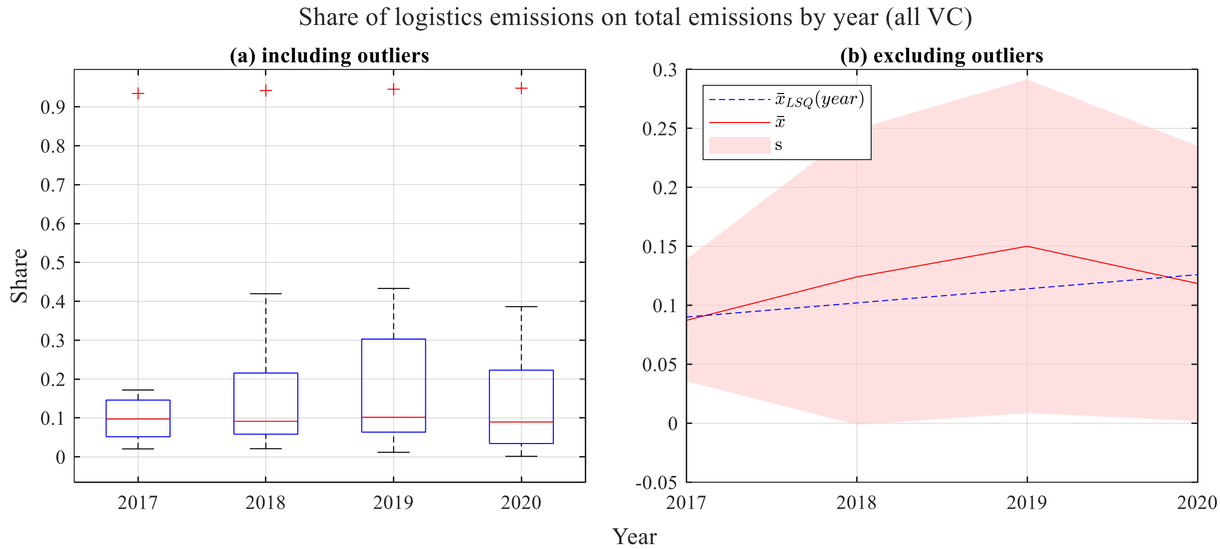

Figure 5. Evaluation of the share of logistics emissions in transport-intensive companies in Austria over time.

Table 4. Share of logistics emissions in transport-intensive companies in Austria over time.

	Total			**Food VC**			**Metal VC**			**Mineral VC**			**Transport VC**			**Waste VC**			**Wood VC**		
Year	$\overline{x}$	s	n	$\overline{x}$	s	n	$\overline{x}$	s	n	$\overline{x}$	s	n	$\overline{x}$	s	n	$\overline{x}$	s	n	$\overline{x}$	s	n
2017	0.0873	0.0517	7	0.082	0.0431	3	0.0685	-	1	-	-	-	0.0205	-	1	0.1719	-	1	0.1041	-	1
2018	0.1241	0.1253	9	0.0907	0.0254	3	0.0583	-	1	0.4195	-	1	0.0211	-	1	0.1198	0.1354	2	0.1061	-	1
2019	0.1501	0.1415	9	0.0937	0.0089	2	0.0636	-	1	0.433	-	1	0.0118	-	1	0.1243	0.1426	2	0.2033	0.1408	2
2020	0.1185	0.1166	14	0.0997	0.0347	5	0.0376	0.0327	2	0.3862	-	1	0.0063	0.0069	2	0.135	0.1548	2	0.2084	0.1361	2
Total	0.1215	0.1141	39	0.0926	0.0296	13	0.0532	0.0219	5	0.4129	0.0241	3	0.0132	0.0081	5	0.1329	0.1038	7	0.1723	0.1019	6

Investigating the share of logistics emissions for all relevant data points independent of the value chain in Figure 5b indicates a peak of relative emissions in 2019, which needs to be taken with caution due to a high standard deviation this year. The rising number of samples and a shrinking standard deviation in 2020 suggests more meaningful results for that year, presenting a share of $\overline{x}_{2020} = 11.85\%$ of emissions accounting for logistics, which is also quite close to the average across all years $\overline{x}_{Total} = 12.15\%$. Fitting the mean shares of each year to a first-order polynomial using least-squares (LSQ) approximation resulted in the equation $\overline{x}_{LSQ}(year) = k \times (2017 - year) + d$, which is evaluated by the dotted blue curve in Figure 5b. The regression indicates that the share of logistics emissions in the total emissions of Austrian transport-intensive companies has slightly increased in recent years by 1.19 percentage points per year, whereas the large uncertainty for the 2019 values might overestimate the real increase. Therefore, we raise the need to validate this further through empirical research in the future.

To conclude on the differences in emissions shares across the investigated value chains, we conducted a one-way ANOVA to assess the impact of the value chain a company is in on a company's share of logistics emissions. The results show that the share of emissions differs statistically and significantly for the different value chains, $F(5,\ 33) = 18{,}424,\ p < 0.001$. A detailed report is provided in the supplementary materials. To gain a better insight into this difference, we evaluated the data for each of the value chains by year and plotted it in Figure 6.

Similar mean shares between 4 and 10% are observed for the Food and Metal VC. The Waste and Wood VC also show similar mean shares of 10 to 20%. Somewhat exceptional are the Mineral VC, with high mean values of around 40%, as well as the Transport VC, presenting very small values of around 2%. The reason for the latter one is the reporting of emissions from the produced vehicles' use phase that is attributed to the Scope 3 emissions of vehicle manufacturers. By including those emissions in the corporate carbon footprint, the total amount of emissions soar, and the share of logistics emissions shrinks.

3.2.4. Analysis of the Results

Larger companies generally adhere to the consideration of the three scopes of the GHG Protocol, but smaller companies or single sites often simply report total emissions without describing which processes are considered in detail. However, differences can also be found in the reports based on the GHG protocol. To elaborate, 11 out of the 24 (45.8%) considered SR do not provide Scope 3 emissions and only one company reports to the full level of detail, as shown in Table 3. Furthermore, different gases were included in the emission reporting in the different SRs. From the 43 data points analyzed, 16 (37.21%) reported only CO_2 emissions, whereas 27 (62.79%) reported CO_2 equivalents, including other GHGs with relevant Global Warming Potentials. Although statistically significant differences across the value chains have been observed, more data would be needed to conclude developments over time. Therefore, Figures 5 and 6 show only initial estimates and should be treated with caution. Since the largest companies in the respective industries were examined and the smaller companies tend not to prepare SRs, we do not assume that an extension to further companies in the transport-intensive industries in Austria is more promising.

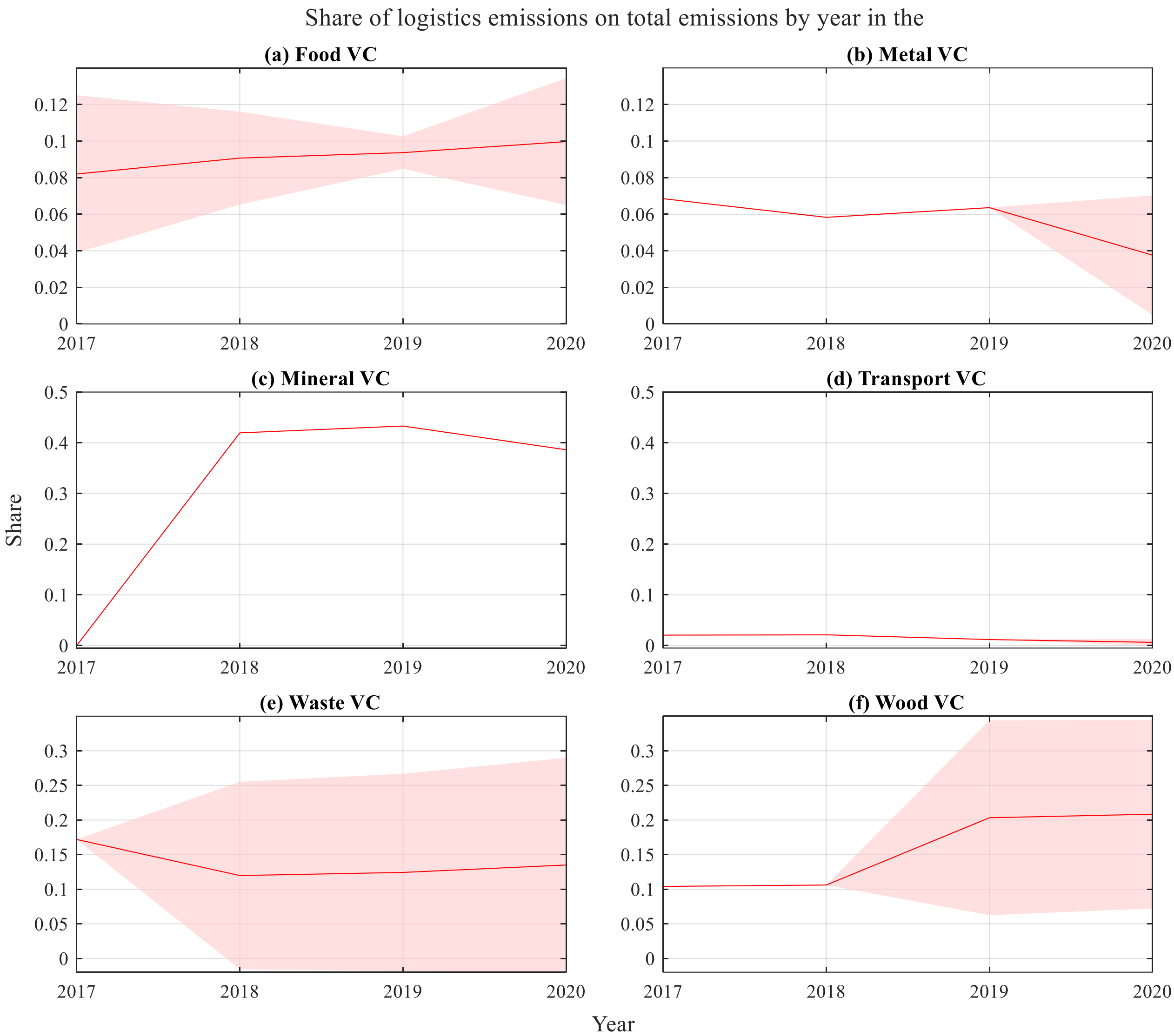

Figure 6. Share of logistics emissions by value chain and year.

As discussed earlier and evaluated in Figure 5, the majority of the data showing the share of logistics emissions lies between 9% and 30%, having the median at approximately 10% and the average across all years and sectors at 12.15%. This is higher than shares that have been reported earlier [24,25], which is plausible due to the population of this research being the transport-intensive business sectors. This finding highlights the validity of the methodology adopted in the first part because the sectors found seem to be more dependent on transport than others and can thus indeed be captioned as the transport-intensive sectors of the economy. Therefore, the answer to the second research question, in comparison to the existing literature, verifies the answer to the first research question.

4. Discussion

The aim of the current research paper was twofold. First, a methodology to identify a country's transport-intensive economic sectors was presented and validated by using Austria as an example. Second, a methodology to assess the amount of GHG emissions that account for logistics relative to a company's total emissions in these transport-intensive sectors was developed and evaluated against the Austrian transport-intensive sectors.

4.1. Identifying Transport-Intensive Sectors

The developed methodology for the first part combines official statistics with methods and data from the EcoTransIT emission calculation tool to provide a straightforward method that is easily applicable to different countries. Applying it to Austria highlighted four main value chains that can be considered transport-intensive value chains in Austria. First, the Metal VC with its raw materials suppliers (NACE divisions B5–B8), the transportation of raw materials (NST division 3), the manufacturers of metal products (NACE divisions C24 and C25), and the transportation of metal products (NST division 10). Statistically, the producers in this VC must share their suppliers with the producers in the Mineral VC (NACE division C23), which, in contrast to metallic ores, access non-metallic mining and quarrying products. The second group of suppliers is the companies from NACE group A, producing crops, animals, agricultural products, and fish for the manufacturers in the Food VC (NACE divisions C10–C12), as well as forestry products for manufacturers (NACE division C16 and C17) in the Wood VC. The finding that the Food VC is among the top GHG emitters underlines statements from other research mentioning that food systems are responsible for as much as one-third of global GHG emissions [57]. Additionally, companies that collect and treat waste (NACE division E38), supporting all the aforementioned sectors of the economy, were found to be major contributors to transport volumes by transporting waste and secondary raw materials (NST division 14). Furthermore, several mentioned value chains process pre-products for the automotive sector, which is why the manufacturing of transport equipment was also found to be a transportation-intensive industry sector. Considering all the demander–supplier relations and having in mind the urge to reduce emissions, a deeper focus on the value chains, i.e., the supplier–demander relationship, will be necessary for the future to reduce transportation demands as well as emissions from transportation. This needs to be elaborated, evaluated, and disseminated by researchers, as well as understood and implemented by practitioners. One possible measure to foster this supply chain-thinking in organizations might be the formation of an organizational unit in which responsibilities for procurement, transport, and production are combined instead of keeping alive separated procurement, logistics, and production divisions [58]. The need to investigate such organizational issues was already highlighted by other empirical research [15].

These discussions show that the application of the developed methodology can generate insights into the freight transportation sector of a country and enables the finding of high macroeconomic emission reduction potentials. Identifying the transport-intensive sectors and value chains of a country can thereby invite researchers and policymakers to lay focus on those sectors in a specific economy and promote emission mitigation research and actions. Applying this methodology to other countries in Europe and consolidating the results will bring indications for European policymakers.

4.2. Assessing the Share of Logistics Emissions

The methodology for the second part comprises the collection of companies in the transport-intensive sectors, the screening of their sustainability reports, and the analysis of their logistics emissions. Applying the method to Austria finds that the share of emissions significantly differs across the value chains and indicates the largest share of emissions in the Mineral value chain and the least in the Transport value chain. Two key findings can be drawn from the second part of the research process. First, potentially low attention paid by managers in the Transport VC to decarbonizing logistics can be explained by the very low share of logistics emissions in this VC. This underlines research indicating that manufacturing firms often concentrate on the decarbonization of their core processes instead of logistics due to higher potential in emission mitigation [24].

On the other hand, a focus to decarbonize transportation in the Mineral VC should be set by researchers and practitioners, as this value chain is, first, among the transport-intensive ones in Austria and decarbonization would have significant macroeconomic effects and, second, companies in this value chain have a significant share of logistics emissions, providing serious microeconomic mitigation potentials and thus larger incentives for managers to focus on logistics emissions. Therefore, companies in the non-metallic minerals sector, including the manufacturing of glass, clay building materials, cement, lime, concrete, and many other important raw materials, that are supported by research and policy could serve as frontrunners, adopting new ways to decarbonize logistics and showing other sectors how to do so.

In general, reporting logistics emissions must be expanded rapidly, as the share of about 30% of companies that report on carbon emissions is quite low. One possible explanation for this small share is the legislative situation in the European Union that excludes SMEs from the obligation of preparing an SR and only obliges public-interest entities with a minimum of 500 employees to prepare an SR [59]. With missing obligation comes missing motivation, it seems. Therefore, we raise the need to incentivize and financially support the creation of SR preparation in line with all three scopes of the GHG Protocol, also for SMEs. Furthermore, key figures of the reports should be made available online and in a computer-comprehensible form so that they can be processed and evaluated as automatically as possible. This can be done, for example, by making Excel spreadsheets available, as it is already being performed by some frontrunner companies [50].

The application of the second part of our proposed methodology thereby highlighted several insights into the structure of the companies in the transport-intensive sectors. By screening the sustainability reports, researchers acquire evidence on how heterogeneous the emission reporting methodology in those sectors is, which companies operate in those sectors and how relevant logistics emissions are for them. The combination of knowledge from the first and second parts of the methodology can be used in this respect to derive tailored recommendations for action for sectors. Companies from transport-intensive sectors, where logistics only account for a small share of total emissions, e.g., have no incentive on their own to reduce these logistics emissions. For such companies, the reporting of emissions should be critically scrutinized and targeted incentives should be developed. In this manner, a matrix of calls for action can be developed, entailing the dimensions "transport-intensiveness" and "share of logistics emissions".

The application of this methodology to other countries and the publication of the results further allows for companies in the transport-intensive economic sectors that did not assess their logistics emissions yet to estimate their share of logistics emissions based on the distribution presented. Companies that do already assess their logistics emissions can benchmark themselves against the mean of all transport-intensive sectors or their respective value chain.

5. Conclusions

The aim of this research was twofold. First, we develop a methodology to identify a country's transport-intensive economic sectors and elaborate on it by using Austria as an example. Second, we present the share of emissions that can be allocated to logistics activities in an average company of those sectors.

The novelty of the methodology presented in the first part is its generic applicability with countries having minimal official transport statistics and the interdisciplinary combination of methodological guidelines from similar studies and the EcoTransIT World emission calculation tool. The transport-intensive sectors are thereby defined as those that produce transport-intensive goods. Further, transport-intensive value chains are defined as supplier–demander pairs among the transport-intensive sectors. For the Austrian case, the Metal, Food, Wood, and Fossil value chains were found to be transport-intensive.

The second part of the presented methodology allows for bottom-up insights into the transport-intensive sectors by suggesting collecting and analyzing sustainability reports of companies in those sectors. Descriptive and statistical analysis, thereby, ensure comparability and validity of the generated findings. For the Austrian case, 71 reports from 179 companies were collected and screened for logistics emission data. Analysis of the reporting methodologies thereby highlights the vast heterogeneity of the reports and suggests more comprehensive and obligatory guidelines.

During the statistical analysis, 97 different distributions were fitted and tested to the emission data and the log-normal distribution was found to be one of the most appropriate ones to describe the statistical distribution of logistics emissions among Austrian transport-intensive companies. The average share of logistics emissions was found to be in the range of 8.7% to 15.01%. To assess sectoral differences, we conducted a one-way ANOVA that shows statistically significant differences in the share of logistics emissions across different value chains.

Regarding the developed methodology, researchers are called to apply it to more countries and, at best, consolidate the results to derive meaningful recommendations for action for policymakers.

For the Austrian case, this study shows a new way to focus on specific sectors of the economy when creating policies for decarbonization and shows the structure of companies in these sectors. Further research will be necessary to investigate temporal trends and more specific sectoral characteristics across transport-intensive value chains.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142215050/s1, ANOVA.

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