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European intermodal freight transport network: Market structure analysis

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ABSTRACT

The analysis of market structure and concentration measures for the Intermodal Freight Transport (IFT) market is important to avoid market failure and to find the areas for policy making to promote IFT market share. This analysis can be performed for separate segments, for example, the market for transshipment service or the market for main-haulage service. However, due to the multistage characteristic of IFT service, the segmental analysis gives an incomplete view of the IFT market at the network level. In a previous paper (Saeedi et al., 2017), we present the Intermodal Freight Transport Market Structure (IFTMS) model to conduct a network-based study of the IFTMS in which distinctive actors (i.e., pre/post haulage operators, terminals, rail/barge operators, transport chains, and corridors) are competing at different levels inside distinctive markets to deliver an integrated IFT service. There are two main challenges in the application of IFTMS model in real cases, for example, the European IFT network. First, the definition of the geographical and spatial border of the transshipment market areas is needed to determine which actors are potentially competing for a specific service demand. The second challenge is the lack of disaggregated data and the consistency of existing data in nodes (i.e., the transshipment areas) and links (i.e., the rail and barge operators). To cope with these challenges, we develop a four-step methodology in which a model-based approach is used to define the geographic boundaries of the transshipment submarkets and provide detailed and consistent data for market analysis. We also apply the IFTMS model to study the market structure of European intermodal network. Our analysis shows that the majority of transshipment markets as well as main-haulage markets are highly concentrated markets. The corridor markets – which include the IFT chains – are unconcentrated markets. Furthermore, the majority of corridors in the European Union are inside highly concentrated origin-destination markets.

1. Introduction

One of the main concerns of the antitrust authorities and policy makers in the field of freight transport is the market concentration and competition level inside the IFT market (Gómez-Ibáñez & de Rus, 2006). An IFT market comprises of different IFT chains—which themselves include different actors providing different services (i.e., pre- and end-haulage, transshipment, and main-haulage). All these IFT chains, together, form an IFT network. Anticompetitive behavior of the IFT operators (e.g., vertical or horizontal integration) could increase the market concentration, and potentially reduce the welfare of the customers (Motta, 2004). In fact, antitrust authorities may scrutinize and limit such business practices because they could harm the competition level in the IFT market (Mazzeo & McDevitt, 2014). Accordingly, an economic analysis of the concentration and the market structure is needed.

The analysis of the market structure and concentration measures for IFT service can be done at several different levels. First, the analysis can be performed for separate segments, for example, the market for transshipment service or the market for main-haulage service (see, e.g., Wiegmans et al., 1999; Makitalo, 2010; Lam et al., 2007; Sys, 2009; Merikas et al., 2014). However, due to the multistage characteristic of IFT service, the segmental analysis gives an incomplete view of the IFT market. In other words, the competition is between IFT chains or even between different corridors to transport the cargo from one "origin" to one "destination"; therefore, a network-based analysis is needed. To analyze the market structure for IFT service, the Intermodal Freight Transport Market Structure (IFTMS) model was developed in our previous study (Saeedi et al., 2017). IFTMS uses graph theory and defines distinct submarkets in an IFT network. These submarkets are represented as nodes (transshipments), links (main-haulages), and paths (corridors, and O-Ds) in the model. Each "corridor" may have multiple IFT chains that include a sequence of nodes and links from an origin to a destination. The IFT chains in a corridor are organized by different forwarders

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to deliver an integrated IFT service to the final customer. As distinctive submarkets inside an IFT network are defined, IFTMS applies a flow optimization model to assign the flow to the IFT network corridors, and then to the respective chains, links, and nodes. Next, the concentration indices— like concentration ratio (CR) or Herfindahl-Hirschman Index (HHI) (OECD, 1990)—for these IFT submarkets are calculated. Further details on the IFTMS model can be found in Appendix E and Saeedi et al. (2017).

To study the IFT market structure at the network level, for example, the European intermodal network, there are two main challenges. First is the definition of the relevant geographical transshipment submarkets. Defining which inland terminals are potentially competing for a specific service demand (and therefore, form a transshipment submarket for that demand area) is an important step when determining whether a market is competitive market or not. The other challenge is the availability of detailed data—especially at the chain level. Although the primary data about the transshipment and main-haulage submarkets are available, the assignment of the capacity of each transport operator to different routes is difficult—if not impossible—to attain. Furthermore, for many corridors, the available data is fragmented, incomplete, and sometimes inconsistent. To cope with these two main challenges, a methodology that is complementary to the IFTMS model is presented in this paper. This methodology applies a conservative model-based approach to define the geographic boundaries of the transshipment submarkets and creates a data set for market analysis. The scientific contributions of this paper are twofold. First, we present a methodology to define the different IFT submarkets in terms of the geographical and spatial aspects, the players, and their respective market shares. For this purpose, a four-step methodology has been developed. Each step uses a model-based approach to characterize a submarket in the IFT network. This methodology is especially useful in cases where only aggregated or incomplete data are available. Lack of detailed data can be caused by limited resources, distinctive and detached obligations for data gathering by legislative organizations, and confidentiality issues (Tavasszy & de Jong, 2014). Second, we apply the presented methodology to analyze the European IFT market at the network level.

The remainder of the paper is organized as follows. In Section 2, the market analysis literature is reviewed. Section 3 presents the methodology. In Section 4 the application of this methodology and the IFTMS model to the EU IFT network is presented. Conclusions and policy implications are given in Section 5.

2. Market analysis literature

IFT is defined as “unitized freight transport by at least two transport modes” (Commission of the European Communities, 2001). In the IFT market, different operators (pre- and end-haulage operators, main-haulage operators, terminal operators, and forwarders) are active and compete with each other in different submarkets (see Fig. 1). The IFT market encompasses all actors operating in all submarkets.

We introduce these submarkets that emerge in the IFT market by means of an example. Suppose that a shipper wants to transfer containers from the Rotterdam area in the Netherlands to the Verona area in Italy. There are many forwarders/LSPs/intermodal operators (further referred to as forwarders) that can arrange for transport and handling. These actors arrange different pre-haulage, transshipment, main-haulage, and end-haulage services, to be able to deliver integrated IFT services to the shippers. The forwarder could hire one of the many truck companies to transit containers from the shipper's location to one of the terminals in the Rotterdam area. These truck companies compete for forwarders' demands, so we have a market where there are demand and supply for trucking services (pre-haulage sub-market). Furthermore, in the Rotterdam area the forwarder needs transshipment services and different terminals in the area; for example, the Rail Service Center (RSC), or ECT Delta, deliver such a service. Therefore, in the Rotterdam area we have a market where there are demand and supply for transshipment services (transshipment submarket). Then, there are different corridors that could be chosen by a forwarder to transport the containers from a terminal in Rotterdam area to a terminal in the Verona area. The forwarder could use any corridor that is competitive (in terms of cost and quality), and directly (or indirectly) connects a particular terminal in the Rotterdam area to a particular terminal in the Verona area. The forwarder could choose the corridor that connects the Rotterdam area to the Verona area through terminals in the Koln area in Germany, whereas other corridors could pass through terminals in Munchen or Nurnberg. These different corridors, which all connect the Rotterdam area to Verona area, make an O-D submarket. When choosing one of the corridors from the O-D submarket, the forwarder is faced with the choice of different rail and barge operators (also called main-haulage) that are active inside the corridors as well as with different terminal operators in the intermediate transshipment areas. If the forwarder chooses the indirect corridor (including handling at that terminal) via Munchen, he or she could choose between IMS or TX Logistik rail companies, for example, to transport the containers from the Rotterdam area to the Munchen area. Here, we could define a main-haulage submarket between the Rotterdam area and Munchen area. Next, he or she could choose between different terminals in the Munchen area: DUSS-Reim, or Munchen-Laim terminals. So in the Munchen area, like the Rotterdam area, we could define a transshipment submarket. From a terminal in Munchen to a terminal in Verona, for example, the Quadrante Terminal, he or she could decide between the intermodal rail operators CEMAT or Kombiverkehr, which are active inside this

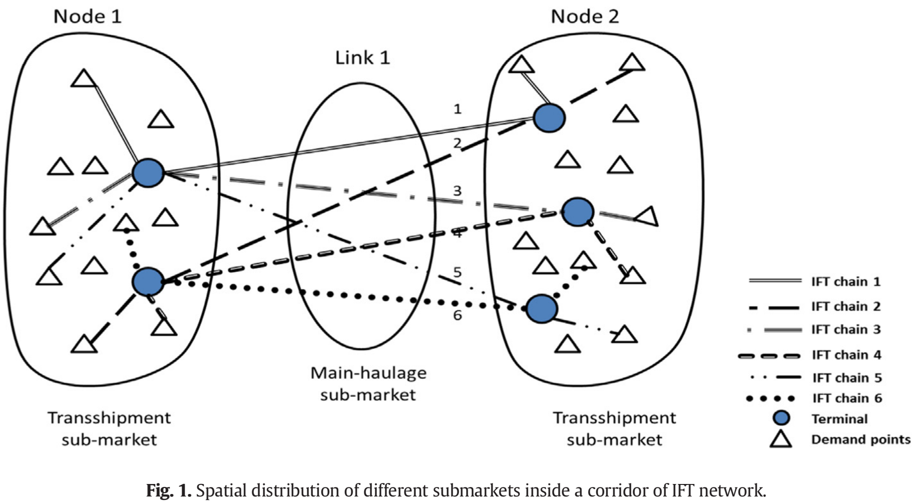

Fig. 1. Spatial distribution of different submarkets inside a corridor of IFT network.
Saeedi et al. (2017).

main-haulage submarket. We can also define a transshipment submarket in the Verona area. Finally, the end-haulage toward the consignee could also be done by a large number of truck companies inside the end-haulage submarket. The structure of each of the aforementioned submarkets can be investigated to understand the competition level or design policies to avoid anti-competitive behavior. In market theories, there are four basic types of market structures: perfect competition, monopolistic competition, oligopoly, and monopoly (Carlton & Perloff, 1999). The oligopoly market can be divided into subcategories. For example, Shepherd (1999) categorized oligopoly into loose oligopoly, tight oligopoly, super tight oligopoly, and dominant player oligopoly. There are a few scientific papers have contributed to the structural analysis of the IFT market. However, according to Macharis and Bontekoning (2004), most papers analyze only selected parts of the IFT market. For example, Wiegmans et al. (1999) analyzed the IFT market in the EU qualitatively based on an extended version of Porter's model of the competitive forces to identify the stakeholders in the terminal market. Makitalo (2010) investigated the Finnish rail industry market, and revealed the largest market entry barriers. In several other research studies (e.g., Crainic et al., 1990; Jourquin et al., 1999; Southworth & Peterson, 2000; Janic, 2007; Wiegmans et al., 2007; Wiegmans, 2005), parts of the IFT network are modeled and optimized. However, there is no paper that analyzes the whole IFT market at the network level.

A main determinant of market structure is market concentration. Market concentration refers to the extent to which a certain number of producers or service providers represent certain shares of economic activity expressed in terms of throughput, for example (OECD, 1990). Indicators such as throughput, revenue, added value, capital cost, or other financial or nonfinancial indices can be used to calculate the degree of concentration in the IFT market (Scherer, 1980). In this paper, due to data availability reasons, we use the throughput of different players as indicators. There are many indices to measure the degree of concentration in the market. The most often used indicators are CR and HHI (US Department of Justice and the Federal Trade Commission, 2010). The CR_x is the sum of the market shares of the x largest players. Typically, the CR_x is calculated for the four largest players (CR_4). The main disadvantage is that two markets with the same high CR_4 levels may have a structural difference because one market may have few players, whereas the other may have many players.

The HHI is the sum of the squares of the market shares of all players in that market and, to simplify the reading, is multiplied by 10,000. It is defined as:

$$HHI = \sum_{i=1}^{n} (s_i)^2 * 10,000, \qquad (1)$$

where the market shares (s_i) satisfy $\sum_{i=1}^{n} s_i = 1$.

The main disadvantage of HHI is that it shows little sensitivity to the entrance of small players into the market (Shepherd, 1999). Although the concentration indices cannot capture the dynamics of the market structure, they are still useful measures. Merikas et al. (2013) and Sys (2009) have applied market concentration indices to the transport markets. Merikas et al. (2013) investigated the change in the structure of the tanker shipping market and its impact on freight rates by applying the CR index and the HHI index. They found that market concentration has increased since 1993. Sys (2009) studied whether the container liner shipping sector as a unimodal freight transport system is an oligopolistic market. She used concentration indices, and based on the degree of concentration, she made judgments about the market structure. In addition to Sys (2009), this paper uses concentration indices as a tool, but the calculations are extended from submarkets to IFT networks.

To measure the concentration inside different submarkets, we use the CR_x (for $x = 1,2,3,4$), and the HHI indices. According to Shepherd (1999), we can determine the market type based on the CR_x and HHI (Table 1). The US Department of Justice and the Federal Trade Commission (2010) also suggests the ranges for the HHI index to categorize the market concentration (Table 2).

Table 1
Different market types based on the Shepherd definition.
Shepherd (1999).

Condition	Market type
$CR_4 < 25\%$	Not-oligopoly
$25\% < CR4 < 60\%$ and $HHI < 1000$	Loose-oligopoly
$CR4 > 60\%$ and $HHI > 1800$	Tight-oligopoly
$CR2 > 80\%$ or $CR3 > 90\%$	Super-tight-oligopoly
$40\% < CR1 < 99\%$	Dominant-player
$CR1 = 100$	Monopoly

3. Methodology to analyze the IFT network market

The presented methodology consists of four different methods that we apply to the different IFT submarkets to define the submarkets in terms of the players and their respective market shares.

3.1. The method of analyzing transshipment submarkets

In the literature, the term *relevant market* describes the areas where competition takes place (Sys, 2009). This relevancy lies in both the product and service similarity and the geographical dimensions. The existence of substantial shipments between two areas indicates the geographic substitution of flows and implies that two areas belong to the same market (shipment pattern analysis) (American Bar Association, 2012). For example, Elzinga & Hogarty (1998) have presented shipment tests that are widely used to assess the competitive effects of a merger. The second method is price correlation analysis, in which the prices of two different suppliers are highly correlated; these two suppliers are considered in the same market. The application of price correlation analysis can be found in Shrieves (1978), Horowitz (1981), Stigler & Sherwin (1985), and Spiller & Huang (1986). Another alternative that is frequently used in freight transport literature—especially to define the market area of a specific terminal—is transport cost (Niérat, 1997). Assessing the transport cost is an alternative to the shipment pattern analysis (Niels et al., 2011). Transport cost could even be included in the price correlation analysis and hypothetical monopolist test, e.g., SSNIP (small but significant and non-transitory increase in price) test, which is used by antitrust authorities. If the transport cost between two areas is more than 5 to 10 percent of the prevailing prices, a monopolist in one area could enforce a SSNIP by 5 to 10% without attracting supply from the other area (Niels et al., 2011). The method for analyzing transshipment submarkets in this paper is based on transport cost. The central concept in this method is the IFT break-even distance, which is defined as the distance in which the total cost of intermodal transport is equal to the costs of truck-only transport (Niérat, 1997). This concept is used in different studies (e.g., Janic, 2007; Janic, 2008; Kim & Van Wee, 2011; Kreutzberger, 2008; Niérat, 1997) to compare the unimodal truck transport and the IFT transport. Niérat (1997) has initially used the IFT break-even distance for rail-haul intermodal transport to define the market area of a terminal. According to his spatial analysis, the terminal market area is part of a family of Descartes's ovals. Limbourg & Jourquin (2010) have argued that if pre- and post-haulage are too costly

Table 2
Different market types based on the U.S. Department of Justice Convention definition.
US Department of Justice and the Federal Trade Commission (2010).

Condition	Market type
$HHI < 1500$	Un-concentrated
$1500 < HHI < 2500$	Moderately-concentrated
$HHI > 2500$	Highly-concentrated

compared to the truck-only transport, the terminal market area is an ellipse. They also argue that, if a terminal provides services in the different directions, i.e. multiple destinations, the transshipments volumes can increase, creating economies of scale and thus lower transshipment costs. In such a case, the market area in each direction will be enlarged. Using this argument and taking into account different directions of the destinations, we can conclude that the shape of the terminal market can be considered as a circle around a terminal. In other words, although in the market analysis for one destination, the terminal is not necessarily located in the center, in the case of multiple destinations, the market area can be considered as a circle for which the terminal is located in the center. Kim & Van Wee (2011) used a simulation method to find the relative importance of influencing factors on IFT break-even distance. They have considered the terminal market area either as a circle or an ellipse. Their findings show that changing the shape of the market from an ellipse to a circle does not have a significant influence on the market analysis. To define the transshipment submarkets in this paper, we consider a circle-shaped market area for a terminal. We also assume that the total intermodal transport demand in an area is concentrated in a demand point, and the terminals in nearby areas around this demand point are supplying homogenous services. With these assumptions, we define the transshipment submarkets from the customer (demand) perspective. In our definition, a transshipment submarket is an area around the demand point in which different terminals are competing with one another to supply the transshipment service to this demand point. These terminals offering intermodal transport services which are competitive compared to unimodal-truck transport.

Let's assume that we have the transport service need from origin, *O*, to destination, *D*. To define the transshipment submarket for Demand Point *O*, we consider two terminals, *A* and *B*. As shown in Fig. 2, to transport goods from Point *O* to Point *D*, two options can be considered. The first is to send the products directly by road from *O* to *D*. The second option is using intermodal transport to send the products by truck to one of the two terminals, *A* or *B*, and then by rail (or barge) to the final destination, *D*. The market area theory implies that using the intermodal transport from Terminal *A* is feasible if the point *O* is inside the circle-shaped market area of Terminal *A*. It might also be possible to use Terminal *B* to send the product from *O* to *D* by an intermodal service because Point *O* is inside the market area of Terminal *B* as well. In general, all the overlapped points of the market areas of Terminal *A* and *B* could use either Terminal *A* or *B* to send the products to the destination, Point *D*. In an extreme case, the market areas of Terminals *A* and *B* may overlap in only one point, *O*. If we assume that the distance of Terminals *A* and *B* are small enough compared to the main-haulage distance, and they supply the homogenous service, the radii of the both market areas of Terminal *A* and *B* are the same (*R*). "Homogenous services" are services of different suppliers that are perceived as identical by the customers (Wiegmans, 2014). In other words, a terminal presents a service that has similar characteristics -e.g., similar service level, and reliability- as services from other competing terminals in the region. To a shipper or forwarder, this means that he or she can replace a service from Terminal A with one from Terminal B. In drawing a circle with the Radius *R* around Point *O*, Terminals *A* and *B* are on the border of this circle. This circle is considered as the transshipment market area for the demand point, *O*, and all terminals inside this area (e.g., Terminal *C*) are market players (i.e., potential competitors to offer transshipment service to the demand point, *O*). The IFT break-even distance literature can give indications to estimate the radius of this transshipment submarket. Depending on different factors (e.g., main-haulage distance), different estimates for the drayage distance are presented (Kim & Van Wee, 2011). For instance, Janic (2007, 2008) argues that the drayage distance (collection/distribution distance by road, as he calls it) is 50 to 75 km in Europe, where the total transport distance is between 650 and 1050 km. Kim & Van Wee (2011) considered 50 km in their work as the drayage distance, assuming the main-haulage of 500 km.

Following the works of Janic (2007, 2008), in Section 4, we consider the terminal market areas in the EU network as the circle-shaped areas where the radii are 70 km. This is followed by the assumption that inside the EU IFT network, the distance between the origins and destinations is in the range of 650 to 1050 km. We also perform a sensitivity analysis for the radii of 90 and 50 km.

3.2. The method of analyzing main-haulage submarkets

To analyze the main-haulage submarket, we assume that main-haulage operators working between two transshipment submarkets form a homogeneous market (Saeedi et al., 2017). With homogenous, we imply that in this market, the transport services (i.e., barge and rail) of different suppliers are perceived as identical by the customers (Wiegmans, 2014). To calculate the concentration, we need the capacity of the different operators inside the main-haulage submarket. Often only the aggregate capacity of the main-haulage operators and their respective active routes are available, and the distribution of the capacity over different routes is lacking for analysis. To find the fair distribution of the capacity of each main-haulage operator in different routes, we apply the proportional fairness algorithm (Bertsekas & Gallager, 1992) in this paper. Proportional fairness considers the transfer of utility between two routes as fair if the increase in operator utility by assigning more capacity to one route is more than the decrease in its utility because of the lower assignment to the other route (Bertsimas et al., 2011). We assume that the capacity deployment among the routes considering their respective lengths (the Euclidian distance between origin-destinations) is a fair way for capacity distribution. It should be noted that applying the fairness algorithm is a conservative way to assign the capacities to the different routes. The main-haulage submarkets could be potentially more concentrated in reality.

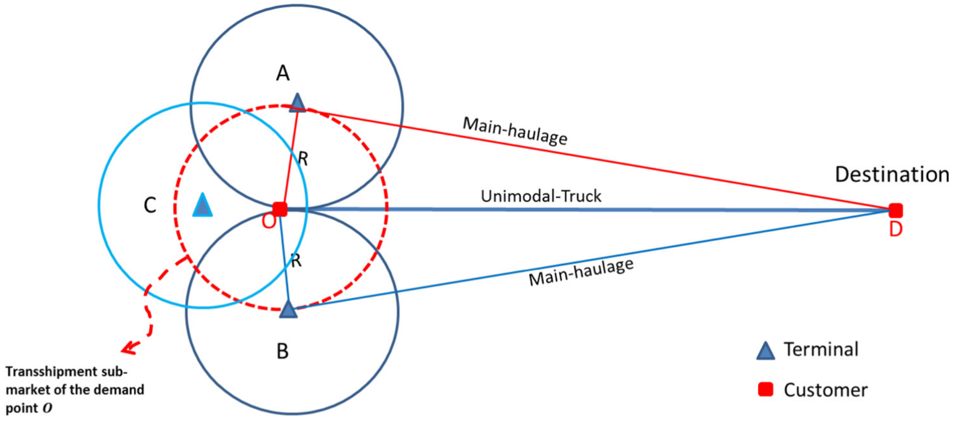

Fig. 2. Conceptual transshipment submarket around the demand.

The IFT network is given by a graph $G=(N,A)$, with node set N and link set A. Each transport operator o works along a set of routes R_o ($R_o=\{R_o^k, k=1, \dots, k_o\}$). Route is the path of each transport operator and consists of a sequential nodes and links inside the IFT network. Based on the fair distribution model (Bertsekas & Gallager, 1992), the operator needs to assign its capacity, C_o,∼ to these routes in a way that the following expression is maximized under a set of constraints:

$$Max \prod_{R_o^k\in R_o} C\left(R_o^k\right) \tag{2}$$

Here $C(R_o^k)$ is the dynamic capacity (in TEU/yr) of the operator O deployed during a year on route R_o^k.

As a first constraint, the dynamic capacity deployed by operator O along all routes in TEU · km/yr must not exceed its total fleet capacity:

$$\sum_{k=1}^{k_o} C\left(R_o^{k_o}\right)\cdot l\left(R_o^{k_o}\right)\le\widetilde{C_o}, \quad \forall o \tag{3}$$

The length of the route $l(R_o^k)$ is given by:

$$l\left(R_o^k\right) = \sum_{i,j\in R_o^k} L_{ij}, \tag{4}$$

where L_{ij} is the length of the link (i,j).

The parameter C_o ∼is defined as:

$$\widetilde{C_o} = C_o * V_o{}^m * T_o, \tag{5}$$

which implies that the total fleet capacity of the operator O in terms of TEU · km/yr is equal to the capacity of the operator in TEU (C_o) multiplied by the velocity of the mode that the operator uses ($V_o{}^m$) and the operating time of that mode (T_o).

The capacity of each link in TEU · km is the summation of the capacity of different routes of different operators that use that link:

$$C_{ij} = \sum_{o\in O}\sum_{k=1}^{k_o} C\left(R_o^k\right)\cdot\delta_{ij,o}^k, \forall(i,j)\in A, \tag{6}$$

where $\delta_{ij,o}^k$ is a binary variable and is 1 if link (i,j) is inside the route R_o^k.

Finally, the summation of the capacity of different routes using a certain node is limited by the capacity of that node:

$$\sum_{o\in O}\sum_{k=1}^{k_o} C\left(R_o^k\right)\cdot\delta_{i,o}^k\le C(i), \forall i\in N, \tag{7}$$

in which $\delta_{i,o}^k$ is a binary variable. It is equal to one if node i is inside the route $R_o^{k_o}$.

As shown in Eq. (7), a parameter in defining the capacity of the main-haulage markets (links) is the capacity of the transshipment submarkets (nodes), $C(i)$, which forces the consistency of the data in these two submarkets.

3.3. The method of analyzing corridor submarkets

Different IFT chains, which are organized by different forwarders, are competing in a corridor submarket. To measure the concentration in this submarket, we should specify the capacity of these IFT chains. The throughput of an IFT chain is in proportion to its "available" capacity, which is the minimum capacity of the terminal and main-haulage operators in that chain (Saeedi et al., 2017). The formulation for this method is as follows:

$$\frac{f\left(x_{i,c}\right)}{C\left(x_{i,c}\right)} = \frac{f\left(x_{j,c}\right)}{C\left(x_{j,c}\right)}, \quad \forall i,j: x_{i,c}, x_{j,c}\in x_c, \tag{8}$$

$x_{i,c}$ represents the IFT chain i in corridor c, and x_c is the set of all chains along corridor c. $C(x_{i,c})$ and $f(x_{i,c})$ are available capacity and the throughput of IFT chain i.

Indeed, the summation of the throughput of the IFT chains should be equal to the throughput of the corridor:

$$\sum_{x_{i,c}\in x_c} f\left(x_{i,c}\right) = f\left(x_c\right). \tag{9}$$

where $f(x_c)$ is the throughput of a corridor for which the calculation is presented in the next section.

3.4. The method of analyzing O-D pair submarkets

In the O-D pairs submarkets, there is competition between corridors in one level and the respective IFT chains in the other level (Saeedi et al., 2017). To measure the concentration in these submarkets, we need the market share of different corridors. In principle, the "available capacity" of a corridor is the minimum capacity of its submarkets (Saeedi et al., 2017). However, because of the overlaps in the transshipment submarkets (nodes) or main-haulage submarkets (links) inside the IFT network, the throughput might be less than the "available capacity" (Saeedi et al., 2017). To measure the throughput, we apply the fairness algorithm for flow distribution in the corridors of a network (Bertsekas & Gallager, 1992). The model is as follows:

$$Max \prod_{x_c\in X} f(x_c), \tag{10}$$

Here, x_c is a corridor, and $f(x_c)$ is its flow. X is the set of all corridors. The summation of the flows of the corridors using node i should be less than or equal to the capacity of that node:

$$\sum_{x_c:(i)\in x_c} f(x_c)\le C(i), \tag{11}$$

and the summation of the flows of the corridors using link (i,j) should be less than or equal to the capacity of that link:

$$\sum_{x_c:(i,j)\in x_c} f(x_c)\le C(i,j). \tag{12}$$

$$f(x_c)\le C(x_c)\ ,\forall c\in C. \tag{13}$$

Eqs. (11) and (12) ensure that the flow of a corridor is consistent with the capacity of the transshipment and the main-haulage submarkets in that corridor. Eq. (13) confirms that the flow of each corridor is not more than its capacity.

4. European IFT network market: analysis and findings

In this section, we apply the IFTMS model to the EU IFT network. First the data and underlying assumptions are described. Next, the results are presented and discussed.

4.1. Data description

The majority of the IFT services in the EU are provided through 34 areas (International Union of Railways, 2004). These areas incorporate about 85% of the total IFT demand (Fig. 3). The data for different IFT submarkets is presented in the following.

- Transshipment submarket
  For the transshipment submarkets the data are gathered from the Inland Links Website. For each region, the Inland-links provides a list of the existing inland terminals, and their respective capacities. In cases when we did not find the capacity data, we gathered capacity data from other sources such as the Intermodal Terminals

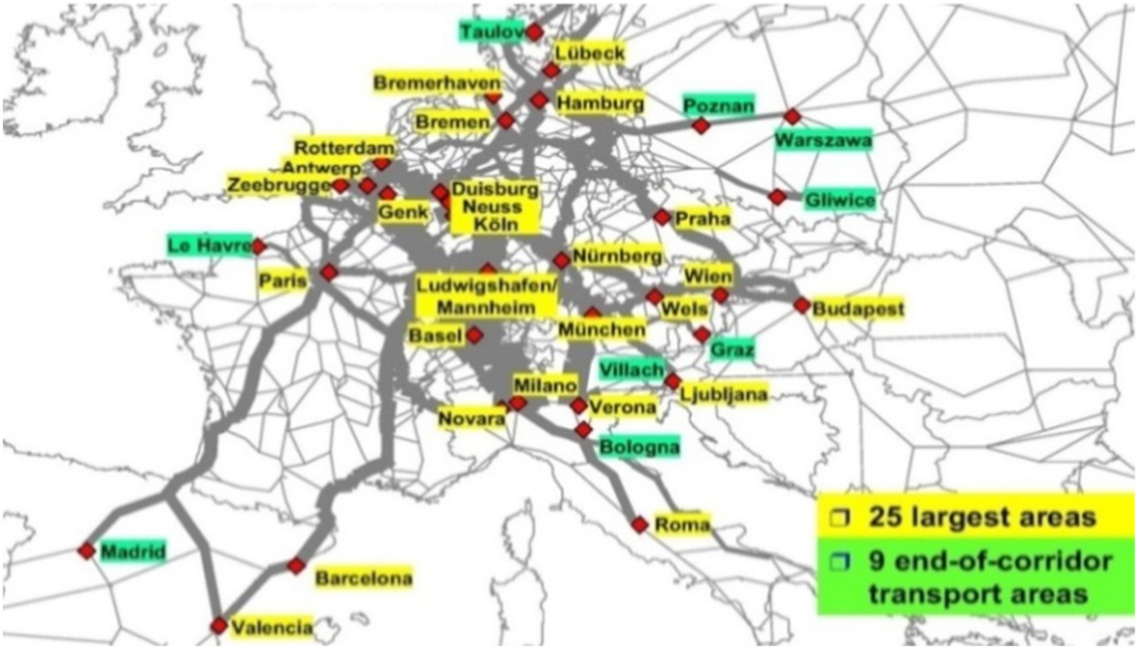

Fig. 3. EU IFT network (International Union of Railways, 2004).

Website, the home page of terminals, or e-mail contact with the terminal operators (Table 3).

We made the following assumptions in data gathering and analysis:

- As mentioned in Section 3.1, a circle-shaped area with the radius of 70 km is considered to define the relevant transshipment submarket. For two demand points (i.e., the Hamburg and Bremen area) no inland terminal exists within 70 km. Thus we have considered the maritime terminals and included their excess capacities in the calculations. Here it could be argued that in these areas, because of the existing of the maritime terminals and their excess capacities, which can be assigned to the continental transport, there is no inland terminal in the nearby areas.
- To calculate the distance between each demand area to different inland terminals in that area, we have used the Inland Links Website. This Web site enables the calculation of the distance between the center of the demand area and the terminal.

– Main-Haulage submarket

The capacity data of the different rail and barge operators are gathered from the Intermodal Yearbook (Gützkow, 2010). The routes where rail and barge operators are working are based on the Intermodal Links Website. Furthermore, to assign the fleet of each operator to different routes (in Eq. (5)), we consider the velocity of the mode m (i.e., the parameter $V_o{}^m$) to be equal to 18 km/h—as the average speed of the rail operators in the EU Report (2016)—and the operating time of mode m (i.e., the parameter $T_o{}^m$) to be 2000 h / year (based on $40\frac{h}{week}{}^{*}50$ week/year). Table 3 shows the list of the data types and sources.

– Corridor submarket

The data for IFT chains competing in each corridor are formed based on the information of main-haulage and terminal operators as mentioned before.

– O-D pair submarket

The data for origins and destinations is based on the presented information in (International Union of Railways, 2004). Sixty-nine corridors are considered based on existing data in the Intermodal Links Website. The list of these corridors can be found in Appendix C.

The summary of the necessary data for different submarkets is presented in Table 3. For different submarkets, different data types are needed, and different sources are used for these data types.

Based on the aforementioned data and assumptions, the application of the IFTMS model to the EU IFT network is presented in the following subsections.

4.2. Analysis of the transshipment submarkets

For transshipment market analysis, the terminals within 70 km are selected, and their market shares are determined based on their throughput. The throughput of a terminal is calculated based on the flow of the corridor to which that terminal belongs. This flow is determined based on Eqs. (10)–(13) and is dependent on the capacity of

Table 3
The data types and sources for different IFT submarkets analysis.

IFT sub-markets	Data type	Source
Transshipment submarket	▪ The list of the inland Terminals in each region (a) ▪ Terminals capacities (a), (b), (c), (d)	a) Inland Links Website b) Intermodal Links Website c) Home pages of terminals d) Email contact with the terminal operators
Main-haulage submarket	▪ Available connections between areas (e) ▪ Total capacity of main-haulage operators (f) ▪ Respective routes of each operator (e)	e) Intermodal Links Website f) Intermodal Yearbook (Gtzkow, 2010)
Corridor submarket	▪ Existing corridors between origins and destinations (g)	g) Intermodal Links Website
O-D pair submarket	▪ The list of the main IFT demand areas in the network (h)	h) International Union of Railways, 2004

Table 4
Structure of transshipment submarkets in the EU.

Market area	CR1	CR2	CR3	CR4	HHI	Shepherd	U.S. Department of Justice Convention
Antwerp	15%	30%	39%	47%	846	Loose oligopoly	Unconcentrated
Bremen	100%				10,000	Monopoly	Highly concentrated
Budapest	59%	100%			5179	Dominant player	Highly concentrated
Duisburg	20%	32%	43%	52%	979	Loose oligopoly	Unconcentrated
Genk	33%	51%	66%	73%	1815	Tight oligopoly	Moderately concentrated
Hamburg	34%	64%	86%	93%	2598	Super-tight-oligopoly	Moderately concentrated
Ludwigshafen	27%	46%	65%	78%	1752	Tight oligopoly	Moderately concentrated
Milano	52%	75%	86%	93%	3431	Dominant-player	Highly concentrated
Munchen	76%	89%	96%	100%	6027	Dominant-player	Highly concentrated
Nurnberg	92%	100%			8587	Dominant player	Highly concentrated
Paris	84%	94%	97%	100%	7158	Dominant-player	Highly concentrated
Praha	65%	84%	99%	100%	4816	Dominant-player	Highly concentrated
Rotterdam	12%	24%	35%	44%	746	Loose oligopoly	Unconcentrated
Verona	71%	100%			5856	Dominant player	Highly concentrated
Wels	67%	100%	100%		5549	Dominant player	Highly concentrated
Wien	70%	100%			5840	Dominant player	Highly concentrated
Zeebrugge	73%	92%	98%	100%	5714	Dominant player	Highly concentrated

that terminal. As a sensitivity analysis, these calculations are replicated for inland terminals within 90 km and 50 km.

The concentration measures of different transshipment market areas are presented in Table 4. In each transshipment submarket, terminals are market players. The majority of markets are highly concentrated with a dominant-player or a tight-oligopoly type. As shown in Fig. 4, the transshipment submarkets in the northern EU are relatively less concentrated than in central and southern areas. It should be noted that in this analysis, we presumed that the terminals in nearby areas around the IFT demand points are delivering substitutable and competitive service. In practice, however, a service of a terminal cannot always be substituted by another one due to operational reasons, railway access, or intermodal operators supply policies and cooperative agreements (International Union of Railways, 2004). This heterogeneity, therefore, could lead to more concentration in the transshipment submarkets.

The results of our sensitivity analysis—by increasing the radii of 70 km to 90 km—is presented in Appendix A. The market structure is not sensitive to increases in the radius in cases; only in Zeebrugge is the change in market structure significant (from Dominant player to Tight oligopoly). In other cases, the influence of an increase in radius is marginal. In addition, we did sensitivity analysis for the 50 km radii (Appendix A). Our findings show the decrease of the radii has little impact on the market structures.

When we look at the whole IFT network, another type of competition is happening inside the transshipment submarkets (nodes) that are bottlenecks. This competition is between corridors, which include these nodes. A bottleneck node is a node for which the throughput is equal to the available capacity (Saeedi et al., 2017). In other words, there is no excess capacity in this transshipment node, and all corridors using that node are basically competing for the available capacity (Saeedi et al., 2017). The analysis of the results shows no bottleneck node in the EU IFT network.

4.3. Analysis of the main-haulage submarkets

To calculate the main-haulage submarkets concentration, we applied the model presented in Section 3.2. To solve the mathematical model, we used the AIMMS optimization package (AIMMS software). The results show the distribution of the capacity of each transport operator in different routes. The concentration measures of different main-haulage submarkets are presented in Appendix B. Based on the results, we can conclude that the main-haulage submarkets in the EU are highly concentrated (see Fig. 5). Considering the conservative nature of our methodology in terms of market concentration, in reality, the main-haulage submarkets in the EU are even more concentrated than what we measured here.

Similar to the transshipment submarket, another type of the competition occurs among corridors that include the bottleneck links (main-haulage submarkets). These corridors are competing for the capacity of those bottleneck links (Saeedi et al., 2017). Our calculations show that in the EU IFT network, there is no bottleneck link.

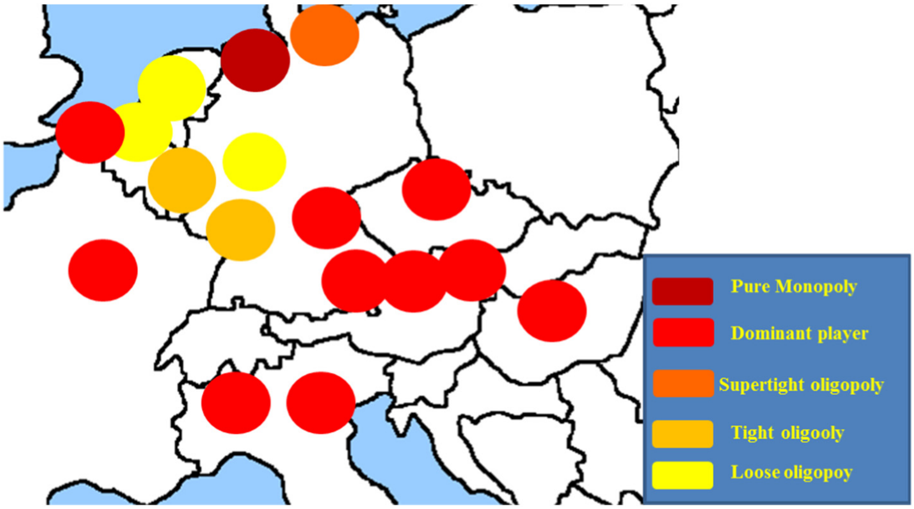

Fig. 4. Geographical distribution of the transshipment submarkets with different market structures in the EU.

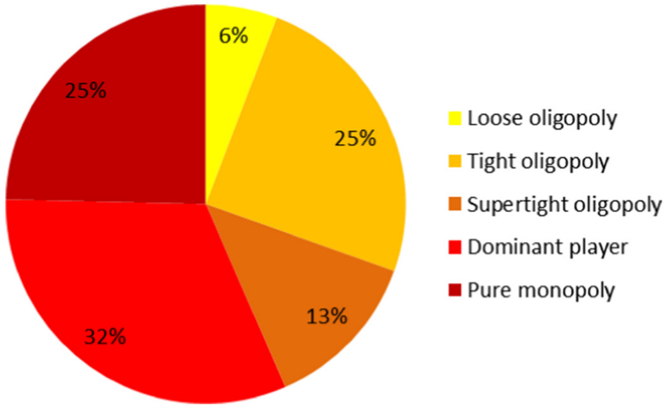

Fig. 5. Types of the main-haulage submarkets in the EU.

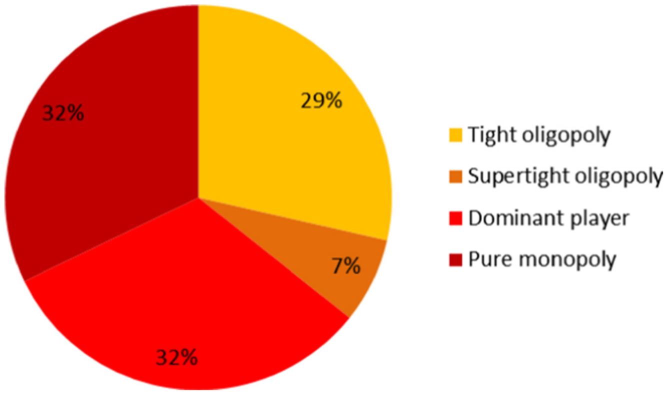

Fig. 7. Different types of the O-D pair submarkets in the EU (corridors as market players).

4.4. Analysis of the corridor submarkets

Inside the corridor submarkets, the IFT chains are the market players. Two parameters are important in the concentration degree inside the corridors: first, the number of segments inside each IFT chain, and second, the number of players inside each segment. In two corridors we have seven segments (four transshipment and three main-haulage submarkets), 18 corridors have three segments (two transshipment and one main-haulage submarkets), and the rest have five segments (see Appendix C). In most of the corridor submarkets, the number of IFT chains is more than 100, and only in two submarkets is the competition between less than 20 IFT chains. Because in the majority of corridors there are too many IFT chains—with almost uniform distribution of the throughput—these corridors are unconcentrated markets. Only in the Zeebrugge-Paris corridor, do we see high concentration. This corridor is a tight oligopoly and a highly concentrated submarket.

Fig. 6 shows the concentration of different sub-markets in different corridors for the EU IFT network. As can be seen in this figure, in the majority of corridors, the transshipment submarkets are the most concentrated submarkets. From a policy-making point of view, this implies that the transshipment submarkets (which include the terminals) have the priority for intervention and capacity extension investments. Fig. 6 also shows the structure of transshipment and main-haulage submarkets in different areas in the EU that can be a basis for regional policy making.

It should be noted that the results of this analysis underestimate the concentration degree inside the corridor submarkets because cooperation between different terminal operators and main-haulage operators in different submarkets to construct IFT chains is not always possible. For example, some rail operators are active in the directions that have access only to certain terminals in some transshipment submarkets. We have not considered these restrictions in our analysis here, but further research can be conducted to address this. Therefore, in general, the corridor submarkets might be more concentrated than what we found here.

4.5. Analysis of the O-D pair submarkets

Given the capacities of the links and nodes from the transshipment and main-haulage submarket analysis, the nonlinear optimization model presented in Section 3.4 is solved to study the concentration of the O-D pair submarkets at the corridor level. The results of modeling are presented in Appendix D and Fig. 7. The majority of the O-D pair submarkets are highly concentrated. The results also show that none of the O-D pair submarkets are un-concentrated markets. For the majority of O-D pairs, there is only one corridor or a dominant one as the market player. In other words, only one main corridor is actively serving that O-D pair intermodal transport service.

Table 5 shows the market types based on the different origins and destinations of the EU IFT network.

The market types of different O-D pair submarkets shows that the O-D pair submarkets originating from Bremen are the most concentrated markets between O-D pair submarkets in the EU IFT network. In addition, the Budapest area is the destination for the most concentrated O-D pair

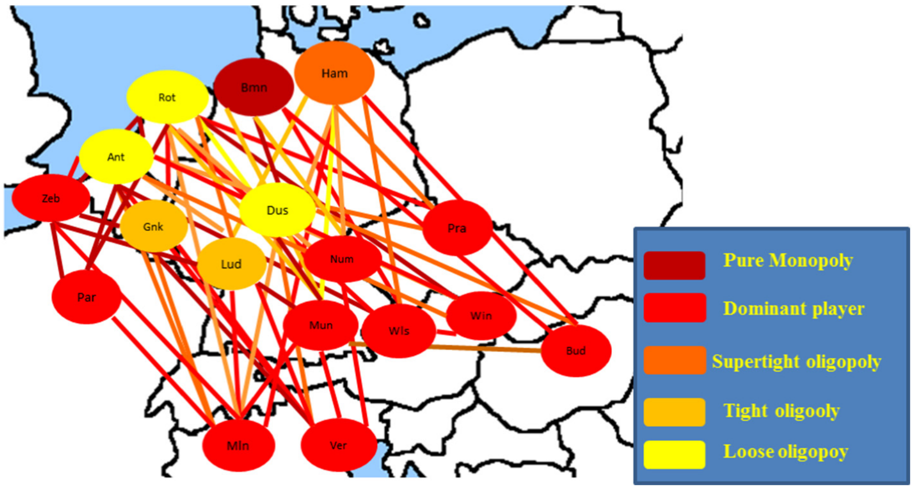

Fig. 6. The geographical distribution of the different transshipment and main-haulage submarkets inside the EU network.

Table 5
Market structure of the O-D pair submarkets based on different origins and destinations (competition between corridors).

Destinations origins	Praha	Paris	Budapest	Verona	Milan	Wien
Hamburg	Dominant-player	Pure-monopoly	Dominant-player	Tight-oligopoly	Supertight-oligopoly	Dominant-player
Bremen	Pure-monopoly		Pure-monopoly	Dominant-player	Dominant-player	Pure-monopoly
Rotterdam	Dominant-player	Pure-monopoly	Pure-monopoly	Tight-oligopoly	Supertight-oligopoly	Tight-oligopoly
Antwerp	Pure-monopoly	Dominant-player	Pure-monopoly	Tight-oligopoly	Tight-oligopoly	Tight-oligopoly
Zeebrugge	Pure-monopoly	Dominant-player		Tight-oligopoly	Tight-oligopoly	Dominant-player

submarkets. On the other hand, the Bremen and Budapest transshipment submarkets are not the most concentrated ones compared to the transshipment submarkets in other EU IFT networks. This clearly implies that we cannot approximate the concentration of the corridor submarkets of specific origin and destination areas, but only look into the market concentration of the origin or destination area.

Fig. 8 illustrates the multilevel nature of market analysis for the EU IFT network. As can be seen, for the subnetwork originating from Rotterdam to Verona, the O-D pair submarket—as the most aggregate level of analysis—indicates the competition between different corridors that form a tight-oligopoly market. The corridor submarkets (e.g., the Rotterdam-Munchen-Verona corridor) are unconcentrated. At the segmental level, the transshipment submarket in Rotterdam is a tight oligopoly, whereas it is a dominant player in Munchen and Verona. The main-haulage submarket between Rotterdam and Munchen is a tight oligopoly, and between Munchen and Verona is a dominant player market. A main implication of these findings is that in policy making for IFT services, we should clearly define the focus of analysis because different levels of market analysis result in different market structures.

5. Conclusion and policy implications

This paper has addressed the subject of competition and market structure in the IFT market. The analysis of market structure is vital for policy makers who aim to promote competition in the IFT market, and increase social economic welfare. Antitrust authorities can benefit from the findings and the presented methodology in this research. In both cases, a main challenge is defining the geographical market, for example, for terminals that are competing inside a transshipment submarket. Furthermore, analyzing the IFT market can be challenging due to multistage characteristics of IFT services. The analysis can be conducted on different levels. We can have a segmental view in which the market concertation for different submarkets (e.g., the transshipment submarket) is analyzed. We can also have a chain perspective in which the competition between different IFT chains in one corridor is studied. At the same time, multiple corridors are potentially competing in the transportation of goods between an origin and a destination. The IFTMS model—as presented in (Saeedi et al., 2017)—helps conduct such a multilevel market analysis. However, the difficulties in applying this model for a case like the European IFT market are the definition of the boundaries of the transshipment markets and the availability of detailed data, especially at the chain level. To cope with these challenges, a methodology that is complementary to the IFTMS model was presented in this paper. This methodology applies a model-based approach—based on fair allocation algorithms—to make the existing high-level data more detailed toward node, link, and corridor data. It should be emphasized that using fair allocation algorithms gives a conservative estimation of market concentration, and the market structure can be more concentrated in reality. Also, the assumptions in defining the relevant

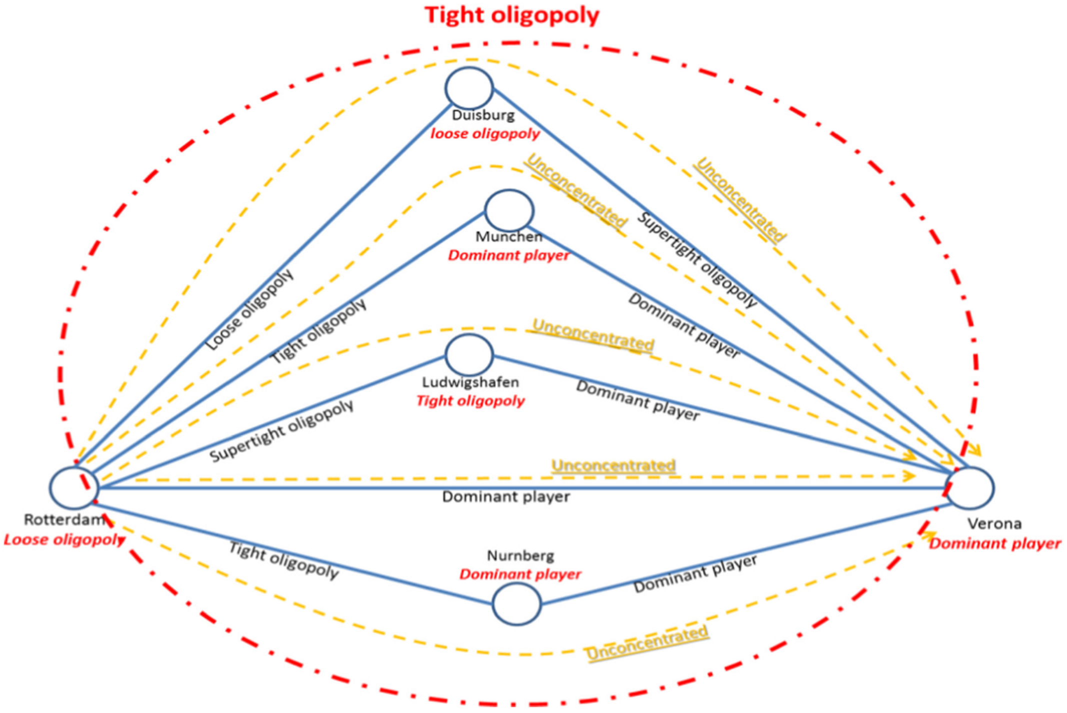

Fig. 8. Different levels of competition inside a sample O-D of the EU IFT network.

geographical transshipment submarkets —that is, the demand for IFT service is concentrated in one demand point and the operators provide homogenous services—provide a conservative measure of concentrations in transshipment submarkets. The policy implication of this is that the presented methodology gives a "lower bound" of actual concentration for different submarkets. In other words, if the results of applying the presented methodology imply a high concentration in one submarket or in one region—that are possible options for policy making and interventions—the actual concentration would be higher than the estimated value.

In this paper, we also applied this methodology to give a picture of the market structure of the European IFT network. The analysis of EU IFT network shows that in most areas the transshipment and main-haulage submarkets are highly concentrated. The majority of corridor submarkets are unconcentrated, and O-D pair submarkets are highly concentrated at the corridor level and unconcentrated at the chain level. As already mentioned, the findings of this study need to be interpreted in a conservative way in light of the methodological limitations and assumptions. These assumptions, lead to a lower bound of market concentration in the EU IFT network. Even this lower bound implies a high level of concentration in transshipment, main-haulage, and O-D pair submarkets, which implies that highly concentrated submarkets exist in the EU IFT network in reality.

In general, this research may have several important implications for policymakers and practitioners. First, this research presents a stepwise methodology for policy-makers, and antitrust authorities to study the market structure of the IFT network (and the potential impacts of anti-competitive business practices like merger and acquisition on the IFT market structure). The model can be used by companies and practitioners to study the potential market implications of their business practices as well. The results of the model's application to EU IFT network provide insight into the market structure and the submarkets with higher priority in terms of competition policy making. Finally, the impact of policies to promote IFT in the EU or the other continents can be evaluated using this model.

One of the main advantages of the presented methodology is the ability to evaluate the IFT market structure in cases when the detailed data is not available. The presented model-based approach also leads to a comprehensive and consistent picture of all flows in different corridors of an IFT network. This approach can be applied in other cases in the transport domain in which sample data need to be constructed from existing aggregate data. Such an application can be a direction for future research in this work. Analyzing the dynamics of market structures in the IFT sector and its evolution over time is another area of interest for future research. The impact of policies to promote IFT in the EU can be studied in such a dynamic market structure analysis. In the higher level of analysis, the competition between the IFT corridors and unimodal-truck transport between different O-D pairs can also be measured by assigning the total freight flows to the freight transport networks.

Appendix A. Sensitivity analysis of transshipment sub-market

Market area	Market type with fixed radius 70 km		Market type after increasing the radius to 90 km	
	Shepherd	U.S. Department of Justice Convention	Shepherd	U.S. Department of Justice Convention
Antwerp	Loose oligopoly	Unconcentrated	Loose oligopoly	Unconcentrated
Bremen	Monopoly	Highly concentrated	Monopoly	Highly concentrated
Budapest	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Duisburg	Loose oligopoly	Unconcentrated	Loose oligopoly	Unconcentrated
Genk	Tight oligopoly	Moderately concentrated	Loose oligopoly	Unconcentrated
Hamburg	Super-tight-oligopoly	Moderately concentrated	Super-tight-oligopoly	Moderately concentrated
Ludwigshafen	Tight oligopoly	Moderately concentrated	Loose oligopoly	Unconcentrated
Milano	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Munchen	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Nurnberg	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Paris	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Praha	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Rotterdam	Loose oligopoly	Unconcentrated	Loose oligopoly	Unconcentrated
Verona	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Wels	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Wien	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Zeebrugge	Dominant player	Highly concentrated	Tight oligopoly	Moderately concentrated

Market area	Market type with fixed radius 70 km		Market type after increasing the radius to 50 km	
	Shepherd	U.S. Department of Justice Convention	Shepherd	U.S. Department of Justice Convention
Antwerp	Loose oligopoly	Unconcentrated	Loose oligopoly	Moderately concentrated
Bremen	Monopoly	Highly concentrated	Monopoly	Highly concentrated
Budapest	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Duisburg	Loose oligopoly	Unconcentrated	Tight oligopoly	Moderately concentrated
Genk	Tight oligopoly	Moderately concentrated	Tight oligopoly	Highly concentrated
Hamburg	Super-tight-oligopoly	Moderately concentrated	Super-tight-oligopoly	Moderately concentrated
Ludwigshafen	Tight oligopoly	Moderately concentrated	Tight oligopoly	Moderately concentrated
Milano	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Munchen	Dominant-player	Highly concentrated	Dominant player	Highly concentrated
Nurnberg	Dominant player	Highly concentrated	Monopoly	Highly concentrated
Paris	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Praha	Dominant-player	Highly concentrated	Dominant-player	Highly concentrated
Rotterdam	Loose oligopoly	Unconcentrated	Loose oligopoly	Unconcentrated
Verona	Dominant player	Highly concentrated	Monopoly	Highly concentrated
Wels	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Wien	Dominant player	Highly concentrated	Dominant player	Highly concentrated
Zeebrugge	Dominant player	Highly concentrated	Dominant player	Highly concentrated

Appendix B. Different structure of main-haulage sub-markets in the EU

Main-haulage sub-market	CR1	CR2	CR3	CR4	HHI
Hamburg-Ludwigshafen	12.7%	25.5%	37.7%	49.7%	1148
Hamburg-Munchen	23.2%	37.6%	51.6%	64.8%	1531
Hamburg-Wels	46.1%	76.9%	100.0%		3608
Hamburg-Budapest	62.0%	100.0%			5291
Hamburg-Verona	34.6%	58.8%	82.3%	100.0%	2649
Hamburg-Milan	55.4%	100.0%			5058
Hamburg-Wien	31.7%	59.2%	82.1%	100.0%	2605
Hamburg-Bremen	52.0%	100.0%			5007
Hamburg-Duisburg	24.0%	48.0%	70.0%	91.0%	2169
Hamburg-Praha	29.0%	55.0%	80.0%	100.0%	2541
Hamburg-Nurnberg	25.2%	48.8%	62.9%	76.7%	1853
Bremen-Ludwigshafen	18.7%	36.9%	53.9%	68.7%	1560
Bremen-Munchen	27.9%	50.7%	69.3%	84.9%	2115
Bremen-Wels	66.8%	100.0%			5565
Bremen-Budapest	62.1%	100.0%			5291
Bremen-Wien	36.5%	64.7%	85.5%	100.0%	2770
Bremen-Duisburg	100.0%				10,000
Bremen-Praha	69.5%	100.0%			5758
Bremen-Nurnberg	20.3%	39.9%	57.3%	72.8%	1709
Rotterdam-Ludwigshafen	38.4%	60.2%	96.6%	100.0%	3284
Rotterdam-Paris	100.0%				10,000
Rotterdam-Munchen	44.5%	69.0%	84.9%	100.0%	3062
Rotterdam-Wels	66.8%	100.0%			5565
Rotterdam-Verona	55.0%	100.0%			5051
Rotterdam-Milan	64.4%	75.9%	85.8%	93.8%	4476
Rotterdam-Wien	100.0%				10,000
Rotterdam-Antwerp	100.0%				10,000
Rotterdam-Zeebrugge	100.0%				10,000
Rotterdam-Genk	64.0%	100.0%			5376
Rotterdam-Duisburg	14.8%	28.4%	42.0%	55.7%	1182
Rotterdam-Praha	100.0%				10,000
Rotterdam-Nurnberg	37.4%	63.2%	81.9%	100.0%	2742
Antwerp-Ludwigshafen	18.9%	66.8%	80.4%	98.3%	3159
Antwerp-Paris	100.0%				10,000
Antwerp-Wels	100.0%				10,000
Antwerp-Verona	55.0%	100.0%			5051
Antwerp-Milan	38.0%	64.6%	84.9%	100.0%	2792
Antwerp-Wien	62.3%	88.3%	100.0%		4699
Antwerp-Zeebrugge	50.0%	100.0%			5000
Antwerp-Genk	100.0%				10,000
Antwerp-Duisburg	12.0%	24.2%	45.6%	55.6%	1765
Zeebrugge-Ludwigshafen	100.0%				10,000
Zeebrugge-Paris	100.0%				10,000
Zeebrugge-Milan	58.8%	100.0%			5156
Zeebrugge-Genk	100.0%				10,000
Zeebrugge-Duisburg	61.0%	100.0%			5241
Genk-Verona	100.0%				10,000
Genk-Milan	62.3%	88.3%	100.0%		3696
Genk-Antwerp	100.0%				10,000
Duisburg-Hamburg	24.3%	45.3%	67.0%	91.3%	2169
Duisburg-Ludwigshafen	33.4%	57.4%	100.0%		3507
Duisburg-Munchen	100.0%				10,000
Duisburg-Wels	54.2%	100.0%			5035
Duisburg-Budapest	37.6%	70.6%	100.0%		3367
Duisburg-Verona	42.5%	80.9%	100.0%		3644
Duisburg-Milan	23.0%	44.9%	61.7%	77.9%	1800
Duisburg-Wien	23.9%	47.0%	67.8%	86.8%	2073
Duisburg-Praha	47.7%	83.7%	100.0%		3836
Nurnberg-Munchen	93.1%	100.0%			8712
Nurnberg-Verona	51.3%	100.0%			5003
Ludwigshafen-Munchen	100.0%				10,000
Ludwigshafen-Wels	53.0%	100.0%			5018
Ludwigshafen-Verona	52.5%	100.0%			5013
Ludwigshafen-Milan	57.5%	100.0%			5113
Paris-Milan	68.1%	100.0%			5655
Munchen-Budapest	100.0%				10,000
Munchen-Verona	51.0%	100.0%			5002
Munchen-Milan	51.0%	100.0%			5003
Wels-Wien	59.0%	100.0%			5161

Appendix C. Number Of IFT chains in different corridor sub-markets

No.	Corridor	No. of IFT chains in the corridor
1	Rotterdam-Koln - Milano	61,200
2	Rotterdam-Koln-Wels-Wien	40,800
3	Antwerp-Koln-Milano	38,556
4	Rotterdam-Koln-Praha	20,400
5	Rotterdam-Koln -Wien	17,000
6	Rotterdam-Ludwigshafen-Wels-Wien	11,520
7	Antwerp-Koln-Wien	10,710
8	Rotterdam-Koln-Budapest	10,200
9	Rotterdam-Koln-Verona	10,200
10	Antwerp-Koln-Budapest	6426
11	Hamburg-Ludwigshafen-Milano	5184
12	Bremen-Koln-Milano	3060
13	Rotterdam-Genk-Milano	2880
14	Antwerp-Rotterdam-Milano	2700
15	Antwerp-Ludwigshafen-Verona	2160
16	Rotterdam-Ludwigshafen-Verona	1920
17	Hamburg-Ludwigshafen-Verona	1728
18	Hamburg-Koln-Praha	1632
19	Bremen-Munchen-Milano	1440
20	Antwerp-Genk-Milano	1296
21	Antwerp-Milano-Paris	1296
22	Hamburg-Munchen-Milano	1152
23	Zeebrugge-Antwerp-Milano	864
24	Hamburg-Koln-Budapest	816
25	Rotterdam-Munchen-Verona	640
26	Zeebrugge-Rotterdam-Milano	600
27	Bremen-Munchen-Verona	400
28	Hamburg-Munchen-Verona	384
29	Antwerp-Rotterdam-Verona	360
30	Antwerp-Rotterdam-Praha	360
31	Rotterdam-Nurnberg-Verona	320
32	Rotterdam-Genk-Verona	320
33	Rotterdam-Milano	300
34	Hamburg-Milano-Paris	288
35	Zeebrugge-Genk-Milano	288
36	Zeebrugge-Ludwigshafen-Milano	288
37	Bremen-Nurnberg-Verona	240
38	Rotterdam-Wels-Wien	240
39	Zeebrugge-Antwerp-Wien	216
40	Antwerp-Milano	216
41	Antwerp-Rotterdam-Wien	180
42	Hamburg-Nurnberg-Verona	160
43	Hamburg-Wels-Wien	144
44	Antwerp-Genk-Verona	144
45	Zeebrugge-Antwerp-Verona	144
46	Zeebrugge-Milano-Paris	144
47	Bremen-Wels-Wien	120
48	Antwerp-Wels-Wien	108
49	Zeebrugge-Ludwigshafen-Verona	96
50	Zeebrugge-Rotterdam-Praha	80
51	Zeebrugge-Rotterdam-Verona	80
52	Antwerp-Wien	54
53	Hamburg-Praha	48
54	Hamburg-Milano	48
55	Zeebrugge-Rotterdam-Wien	40
56	Bremen-Praha	40
57	Rotterdam-Praha	40
58	Rotterdam-Verona	40
59	Antwerp-Verona	36
60	Hamburg-Wien	32
61	Hamburg-Verona	32
62	Zeebrugge-Genk-Verona	32
63	Rotterdam-Paris	30
64	Antwerp-Paris	27
65	Zeebrugge-Milano	24
66	Rotterdam-Wien	20
67	Bremen-Budapest	20
68	Hamburg-Budapest	16
69	Zeebrugge-Paris	6

Appendix D. The results of O-D pair sub-markets analysis

		Indices	Destinations					
			Praha	Paris	Budapest	Verona	Milano	Wien
Origins	Hamburg	CR1	50%	100%	50%	25%	33%	50%
		CR2	100%		100%	50%	67%	100%
		CR3				75%	100%	
		CR4				100%		
		HHI	5000	10,000	5000	2500	3333	5000
	Bremen	CR1	100%		100%	82%	50%	100%
		CR2				100%	100%	
		CR3						
		CR4						
		HHI	10,000		10,000	7049	5000	10,000
	Rotterdam	CR1	50%	100%	100%	17%	33%	33%
		CR2	100%			33%	67%	67%
		CR3				50%	100%	100%
		CR4				67%		
		HHI	5000	10,000	10,000	1667	3333	3333
	Antwerp	CR1	100%	50%	100%	25%	50%	17%
		CR2		100%		50%	100%	33%
		CR3				75%		50%
		CR4				100%		100%
		HHI	10,000	5000	10,000	2500	5000	3333
	Zeebrugge	CR1	100%	86%		20%	42%	50%
		CR2		100%		41%	56%	100%
		CR3				62%	71%	
		CR4				100%	86%	
		HHI	10,000	7569		2729	2603	5000

Appendix E. Review of the IFTMS model

In this appendix, we give an overview of IFTMS model (Saeedi et al., 2017). The model aims to provide a mathematical method to allocate flows to nodes, links, and corridors, and to various players on the network while taking into account their capacities. The network is given by graph $G=(N,A)$ with node set N and link set A. The flow f_a on link $a\in A$ does not exceed link capacity, i.e., $0\leq f_a\leq c_a$. For any node $n\in N$ the flow is also assumed $0\leq f_n\leq c_n$ for $n\in N$. For any corridor $\pi\in\prod$ that originates from o and is destined to d, we may establish a flow f_π through the corridor in a consistent way. A corridor (path) π is associated with a sequence of nodes $(n_1,\ldots,n_{m+1})$ and links $(a_1,\ldots,a_m)$ where $a_j=(n_j,n_{j+1})$. By abuse of notation, we write $a\in\pi$ or $n\in\pi$ whenever the link a or the node n is part of the corridor π. Define the link-corridor (and similarly, node-corridor) incidence matrix as follows: Let $\delta_{a\pi}=1$ whenever $a\in\pi$ and $\delta_{a\pi}=0$ otherwise. The flows f_π satisfy $f_a=\sum_{\pi}\delta_{a\pi}f_\pi$ and $f_n=\sum_{\pi}\delta_{n\pi}f_\pi$. In case the incidence matrices have rank equal to the number of corridors, then the corridor flows can also be constructed from the link (or node) flows by applying the right-inverse of the link-corridor (node-corridor) incidence matrix. In case the incidence matrix is not of full rank, which may happen even in the case of a single OD pair, then the corridor flows are not uniquely defined by the link and node flows.

The flow size is equal to the total flow through all corridors, i.e., $|f|=\sum_{\pi\in\prod}f_\pi$. Alternatively, the flow size equals the total outflow from the origin and the total inflow to the destination, i.e., $|f|=f_o=f_d$. A corridor π has capacity $c_\pi=\min\{c_a,c_n|a\in\pi,n\in\pi\}$. The allocation of the total flow $|f|$ to corridors is proportionally fair when (Bertsekas & Gallager, 1992):

$$Max\prod_{\pi\in\prod}f_\pi, \tag{a}$$

$$\sum_{\pi}\delta_{n\pi}f_\pi\leq c_n, \tag{b}$$

$$\sum_{\pi}\delta_{a\pi}f_\pi\leq c_a, \tag{c}$$

$$f_\pi\leq c_\pi,\ \forall\pi\in\prod. \tag{d}$$

Hence, we maximize the product of the corridor flows, subject to three constraints. Eqs. (b) and (c) constrain the summation of the flows of the corridors using node n or link a to be less than or equal to the capacity of that respective node or link. Eq. (d) forces that the assigned flows to the corridors not be more than the capacity of the corridors.

We argue that in this manner, the flow will be allocated to all corridors (see Eq. (a)), and our allocation mechanism does not introduce market concentration artifacts as flow is rationed proportional to available capacities. This will allow us to study market concentration as it emerges from the structure of the capacitated network.

We now consider the situation when multiple actors have available capacity on nodes, links, and corridors, and we study the corresponding submarkets. The node (transshipment) submarket M_n has size f_n and capacities c_n^k, where $k\in P_n$ are market players in the node market. By definition $c_n=\sum_{k\in P_n}c_n^k$. The flow allocation is proportional, i.e. $f_n^k{:=}f_n\frac{c_n^k}{c_n}$. Similarly, for link market M_a, we get $f_a^l{:=}f_n\frac{c_n^l}{c_n}$ for players $l\in P_a$ in the link market. Players in the OD-pair market M_{od} are identified with corridors, so the allocation of total flow to players is equal to the allocation of flow to corridors, which we have discussed above. A chain (p) within this corridor is associated with a service that uses capacities of certain operators inside nodes and links. If operators $k_i \in P_{n_i}$ $(k_i \in k, P_{n_i} \in P_n)$ for $i = 1, \dots, m+1$, and $l_j \in P_{a_i}$ $(l_j \in l, P_{a_i} \in P_a)$ for $j = 1, \dots, m$ provide capacity to chain p (and we write $p \in \pi$), then the chain is given by $(c_{n_i}{}^{k_i}, c_{a_j}{}^{l_j})$.

We define the p_o as a chain with the least capacity inside the corridor π – i.e., a chain consist of players which have minimum capacity inside nodes and links:

$$p_o := \left\{ \left(c_{n_i}^{k_{io}}, c_{a_j}^{l_{jo}} \right) \middle| \; c_{n_i}^{k_{io}} = \min\left\{ c_{n_i}^{k_i} \right\}, c_{a_j}^{l_{jo}} = \min\left\{ c_{a_j}^{l_j} \right\}, \mathrm{i} = 1, \dots, m+1, j = 1, \dots, m \right\} \tag{e}$$

Then considering these least capacity chain (p_o), we assign a weight to different chains, by dividing the capacity of the players in nodes and links to the capacity of the players inside least capacity chain (p_o), and then make a summation on these numbers.

$$w_p := \left\{ \sum_i \frac{c_{n_i}^{k_i}}{c_{n_i}^{k_{io}}} + \sum_j \frac{c_{a_j}^{l_j}}{c_{a_j}^{l_{jo}}}, \quad p \in \pi \right\} \tag{f}$$

We allocate flow proportional to the weights, and we set the flow of the chain p in the corridor π as follows:

$$f_\pi^p := \frac{w_p}{\sum w_p} . c_\pi \tag{g}$$

Additional submarkets can be defined for those nodes and links that are bottlenecks in the corridors. These corridors effectively compete for capacity on those nodes and links. B denotes the set of bottlenecks in the network with respect to the flow f, that is,

$$B := \{ n \in N | f_n = c_n \} \cup \{ a \in A | f_a = c_a \} \tag{h}$$

We have for $a \in A$ that $c_a = f_a = \sum_\pi \delta_{a\pi} f_\pi$ and for $n \in N$ that $c_n = f_n = \sum_\pi \delta_{n\pi} f_\pi$. The allocation of link a (or node n) capacity to the corridor π is given by f_π.

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