Structure and recent dynamics of the industrial roundwood trade from a network analysis perspective: towards a monopsonistic situation?

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01 Context - Global and scientific issues, objectives of the study.

GLOBAL ISSUES

From the use of wood products to international trade

Wood as a substitute…

…to fossil fuels and mineral materials (Canadell and Raupach, 2008; Geng at al., 2017; Leskinen et al., 2018).

Growing integration in energy transition policies or as a sustainable material for construction (IRENA, 2020; Skea et al., 2022).

Uneven distribution

Forest resources are unevenly distributed between countries (FAO, 2020, p. 11-24).

There are unbalanced production and consumption of wood products at a regional level (Müller et al., 2004).

Trade to meet demand

International trade of wood products allows to redistribute surpluses resulting from production to countries with demand deficits.

This allows to meet global demand.

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A COMPREHENSIVE STUDY OF THE INTERNATIONAL TIMBER TRADE

Spatial scales

From global to macroregional, national, or subnational scales (Müller et al., 2004; Caurla et al., 2013; Buongiorno, 2015; Rougieux, 2017…)

Variety of products

Paper and pulp (Johnston, 2016; Latta et al., 2016), **fuelwood** (Raunikar et al., 2010), **lumber** (Johnston and van Kooten, 2017), **aggregated forest products** (Guan et al., 2019)…

Objectives

Analyzing the trade mechanisms (Zhu et al., 2001; Sun et al., 2010), **or focusing on forecasting or policy analysis** (Buongiorno, 2016; Johnston, 2016).

Potential determinants

Liberalization and free trade agreements (Turner et al., 2001; Zhu et al., 2001), **tariffs and non-tariffs barriers** (Turner et al., 2008b; Sun et al., 2010), **trade disputes** (Johnston and Parajuli, 2017; van Kooten and Voss, 2020)…
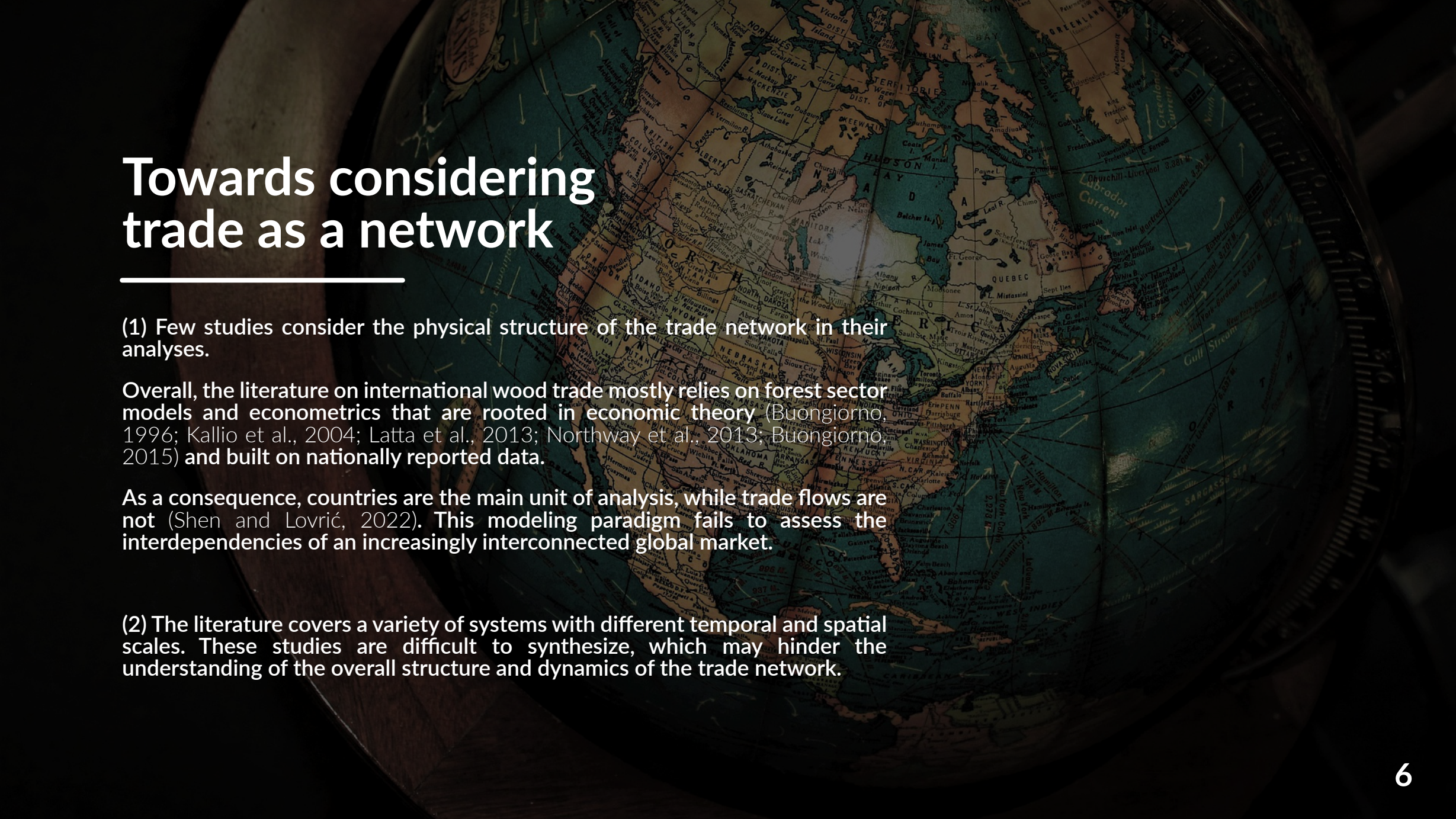
Towards considering trade as a network

(1) Few studies consider the physical structure of the trade network in their analyses.

Overall, the literature on international wood trade mostly relies on forest sector models and econometrics that are rooted in economic theory (Buongiorno, 1996; Kallio et al., 2004; Latta et al., 2013; Northway et al., 2013; Buongiorno, 2015) **and built on nationally reported data.**

As a consequence, countries are the main unit of analysis, while trade flows are not (Shen and Lovrić, 2022). **This modeling paradigm fails to assess the interdependencies of an increasingly interconnected global market.**

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As a consequence, countries are the main unit of analysis, while trade flows are not (Shen and Lovrić, 2022). This modeling paradigm fails to assess the interdependencies of an increasingly interconnected global market.

(2) The literature covers a variety of systems with different temporal and spatial scales. These studies are difficult to synthesize, which may hinder the understanding of the overall structure and dynamics of the trade network.
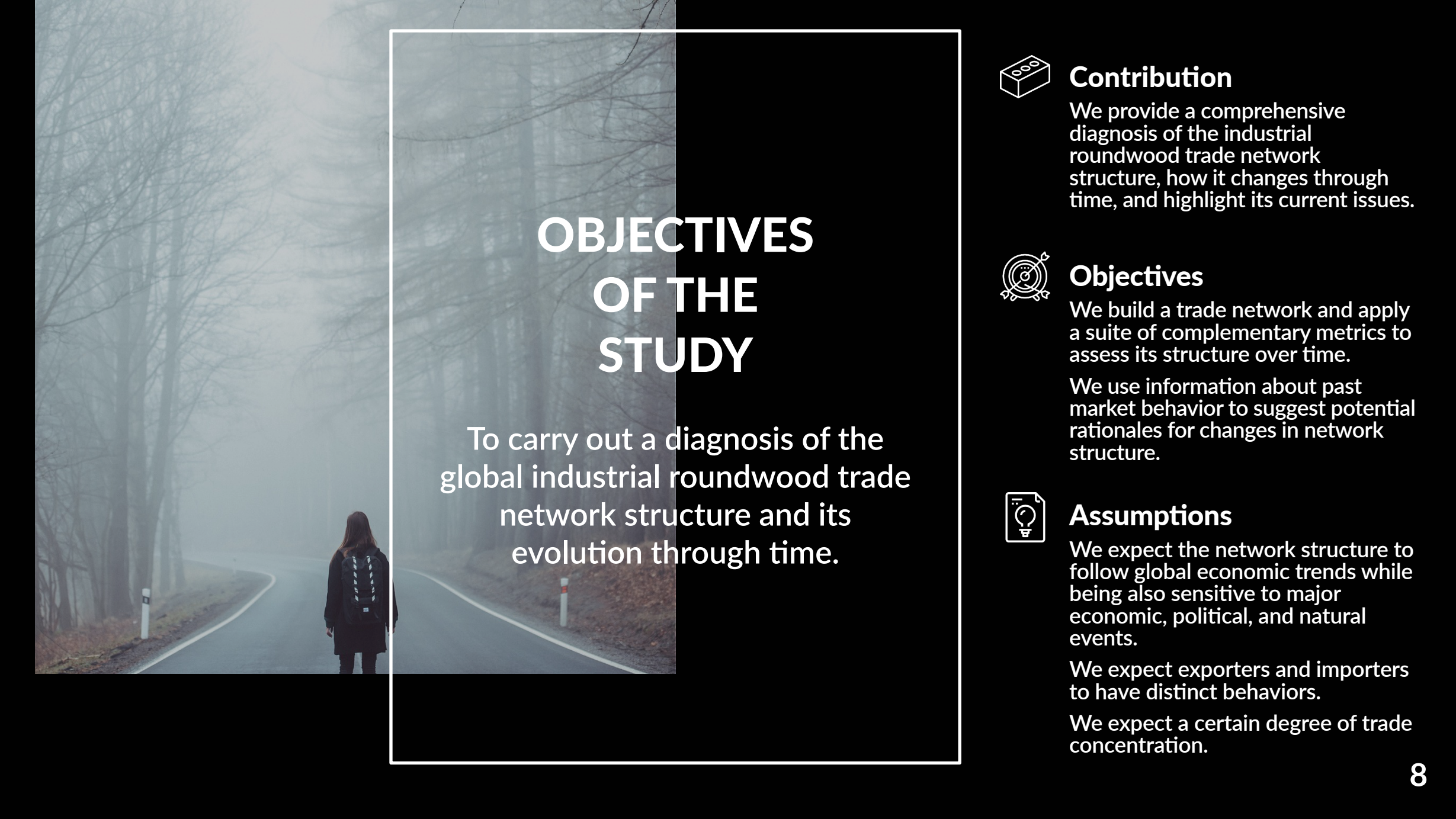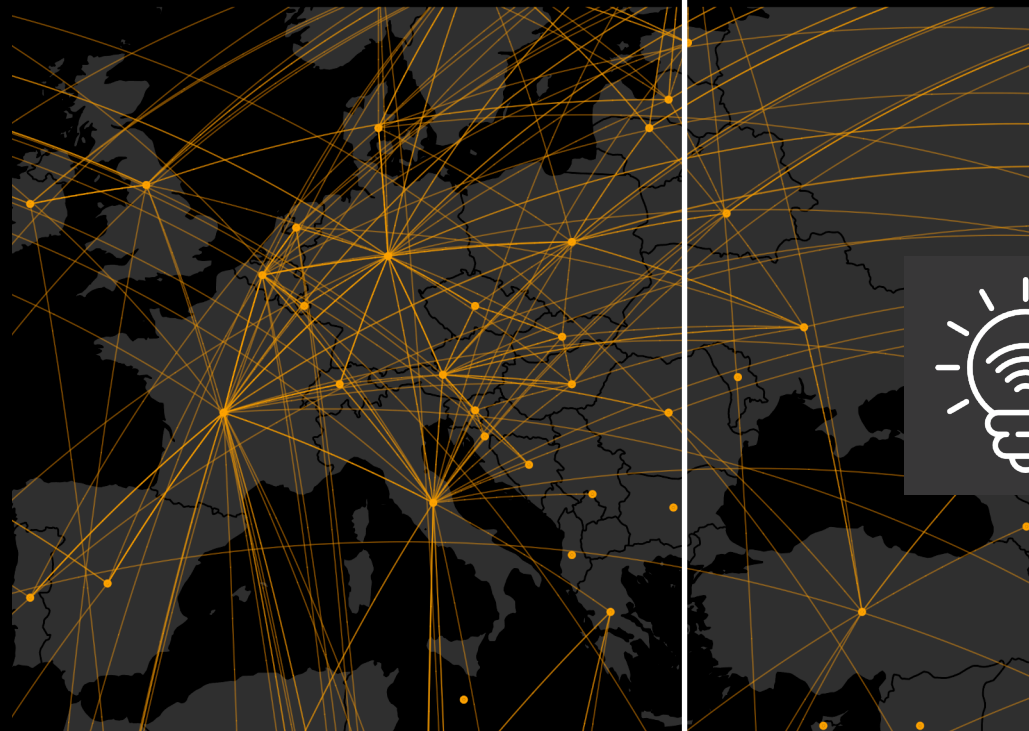
An approach based on network theory

We consider the **trade flows between countries as the unit of analysis.**

This allows a **deeper understanding of the trade structure** and complements the existing literature on international wood trade.

Four previous studies use network theory (Lovrić et al., 2018; Long et al., 2019; Zhou et al., 2021; Shen and Lovrić, 2022) **but:**

(i) They do not offer a complete description of the structure of the commercial network

(ii) A description of the evolution of the network structure over time is missing

OBJECTIVES OF THE STUDY

To carry out a diagnosis of the global industrial roundwood trade network structure and its evolution through time.

Contribution

We provide a comprehensive diagnosis of the industrial roundwood trade network structure, how it changes through time, and highlight its current issues.

Objectives

We build a trade network and apply a suite of complementary metrics to assess its structure over time.

We use information about past market behavior to suggest potential rationales for changes in network structure.

Assumptions

We expect the network structure to follow global economic trends while being also sensitive to major economic, political, and natural events.

We expect exporters and importers to have distinct behaviors.

We expect a certain degree of trade concentration.

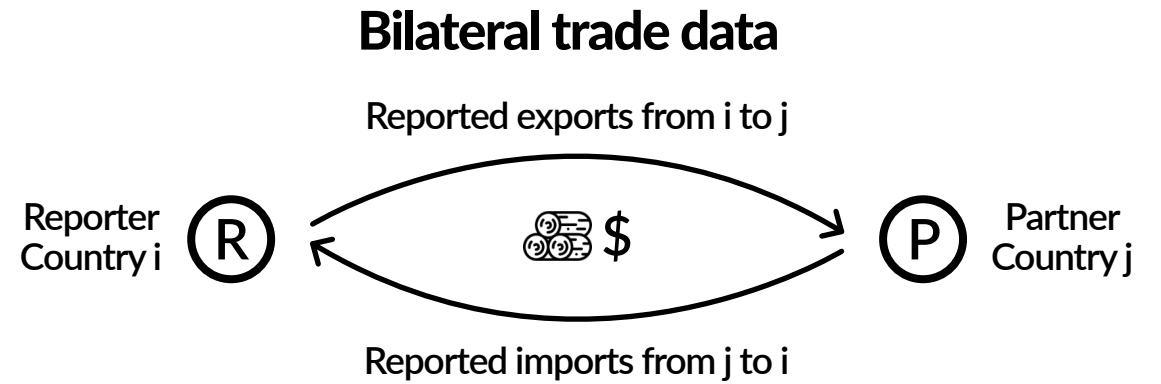02 Materials and method - Bilateral trade data from a network theory perspective

FAOSTAT Forestry Trade Flows database

Data on the **bilateral import and export quantity** (in m3) and **value** (in 1000 US$) of **forest products** at the **national level, from 1997 to 2018.**
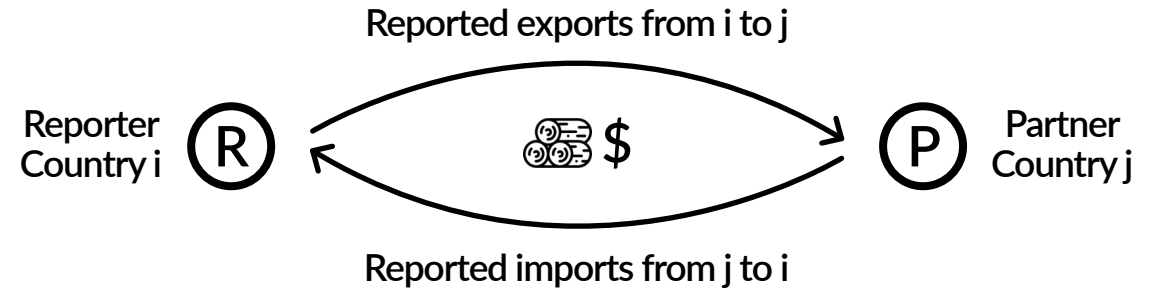
We extracted data on **import and export values for industrial roundwood** for all available years.

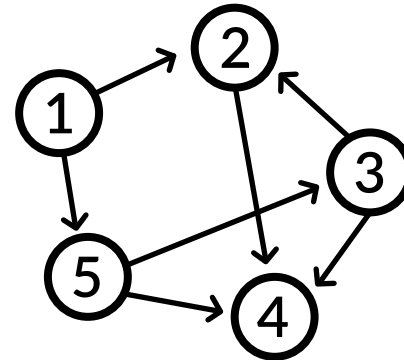# PROCESSING BILATERAL TRADE DATA INTO NETWORK ANALYSIS MATHEMATICAL OBJECTS

Bilateral trade data

Reported exports from i to j

Reporter Country i (R) ⟷ 🪵 $ ⟷ (P) Partner Country j

Reported imports from j to i

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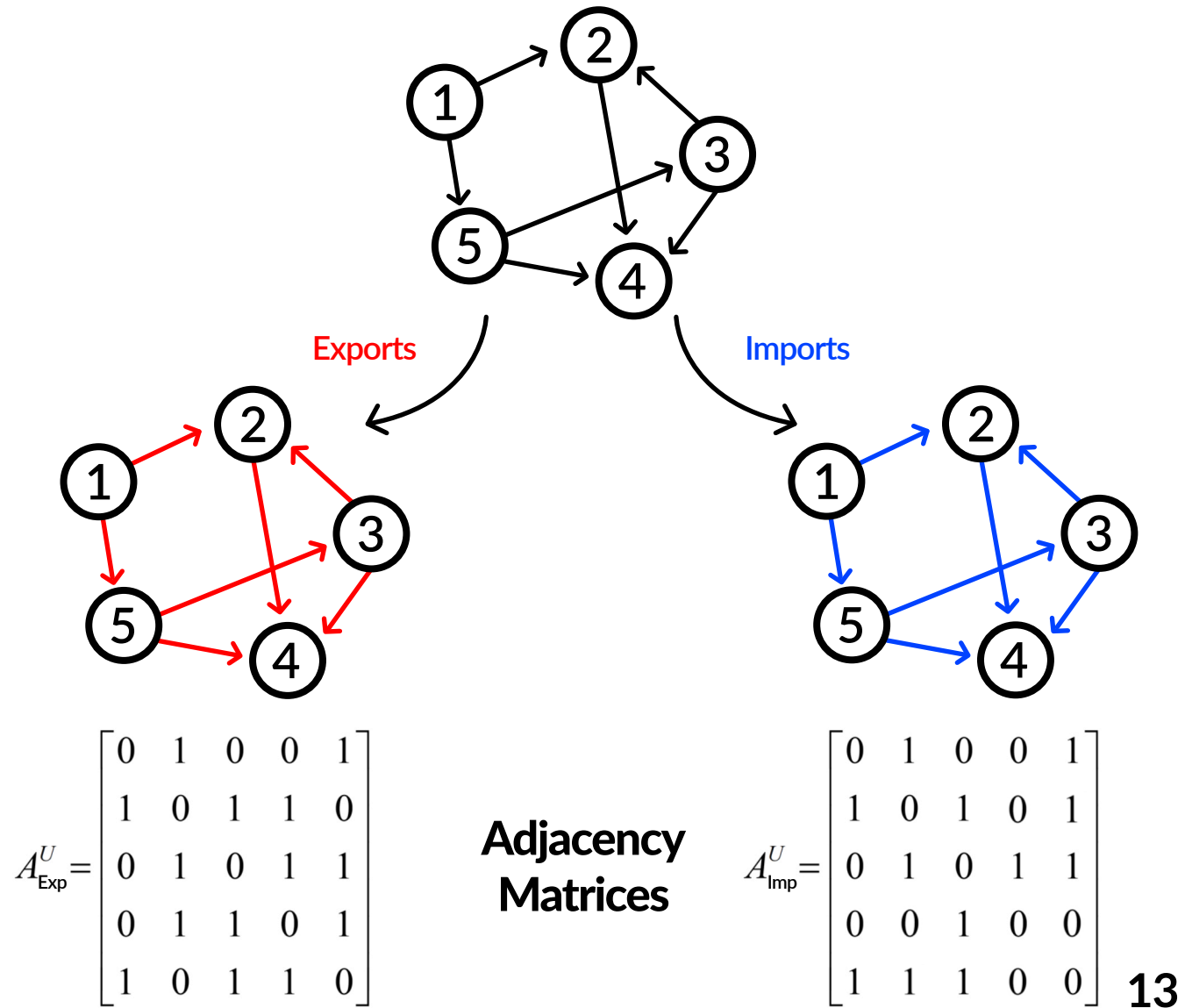
Reported imports from j to i

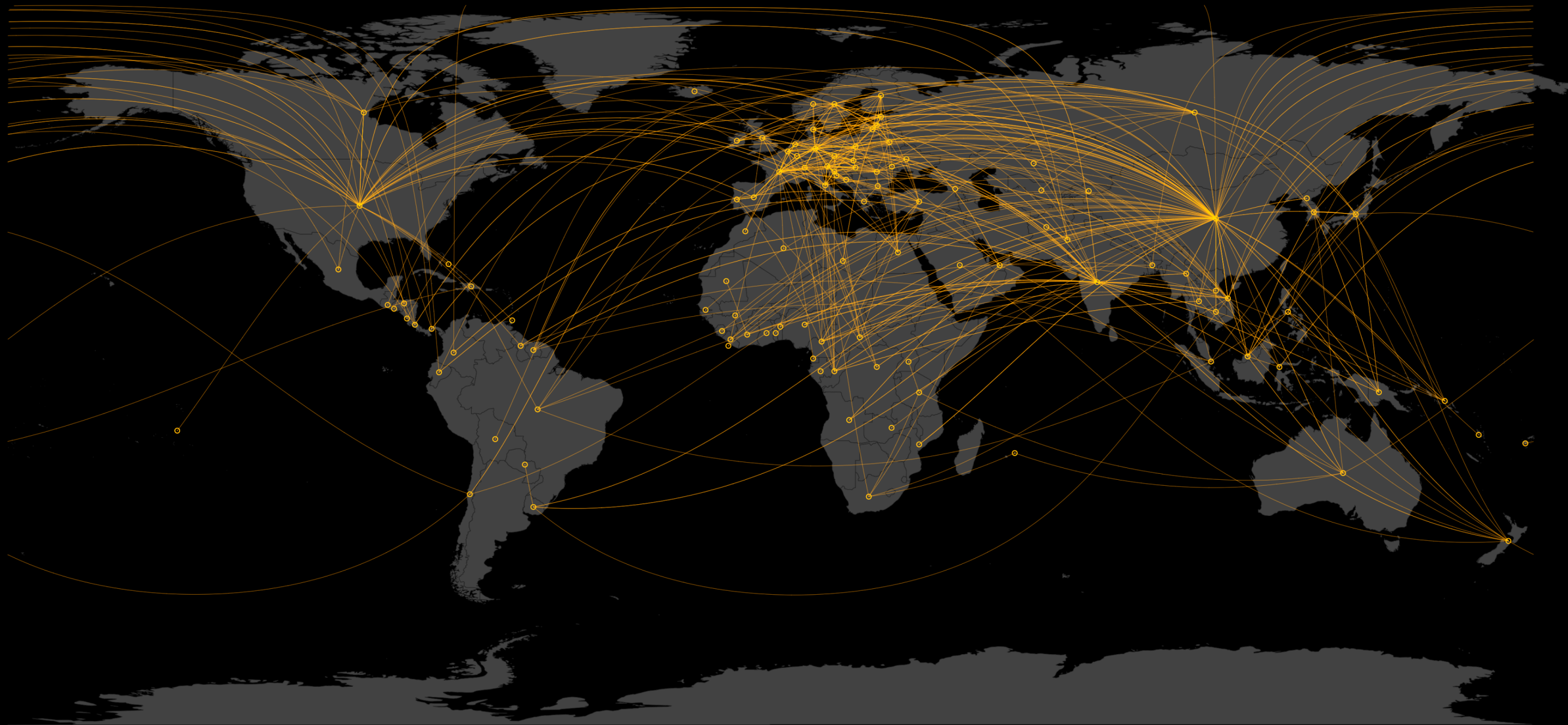If there is one non-zero trade flow from i to j, we count a trade connection from i to j of 1.

Unweighted and directed Networks

PROCESSING BILATERAL TRADE DATA INTO NETWORK ANALYSIS MATHEMATICAL OBJECTS

Unweighted and directed Networks

Exports

Imports

Adjacency Matrices

$$A_{\mathrm{Exp}}^{U} = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

$$A_{\mathrm{Imp}}^{U} = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \end{bmatrix}$$

World exports of more of $500 billion or more of industrial roundwood in 2016

COMPLEMENTARY METRICS TO ASSESS NETWORK STRUCTURE

(Barrat and Weigt, 2000; Newman et al., 2001; Albert and Barabási, 2002; Newman, 2003; Baggio et al., 2011; Shanafelt et al., 2017; Salau et al., 2022)

Network size and composition

Number of nodes: Total number of countries, exporters, and importers involved in trade.

Total number of importers and exporters: Composition of the trade network.

Total amount of trade value: Overall economic value of the network.

Network connectedness

Mean number of connections per node: Average number of trading partners per country.

Variance in the number of connections per node: Variation in the number of trading partners per country relative to the mean.

Skewness in the number of connections per node: Proportion of low to highly connected countries in the network.

Network typology

Degree distribution: Distribution of the number of trading partners per country. Its shape yields information on how countries choose their trading partners.

Mean local clustering coefficient: Probability that two connected countries share a common trading partner.

Trade concentration

Herfindahl-Hirschman index / Shannon index: Diversity indexes computed on market shares. It yields information on the concentration of the export and import markets.

Countries' contribution to trade: Compare the total traded value with and without each country. Shows which countries contribute the most to the import and export markets.

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03 Some results and discussion points

Over our study period, the number of countries involved in the trade of industrial roundwood slightly varied.

Market showed an overall increase in value.

There have been more importers than exporters over the studied period.

The network composition in terms of number of exporters and importers changed from 1997 to 2018.

We notice several drops in the number of exporters or importers and in the traded value of industrial roundwood.

N.B.: Some disparities can be seen in total value traded between exports and imports.
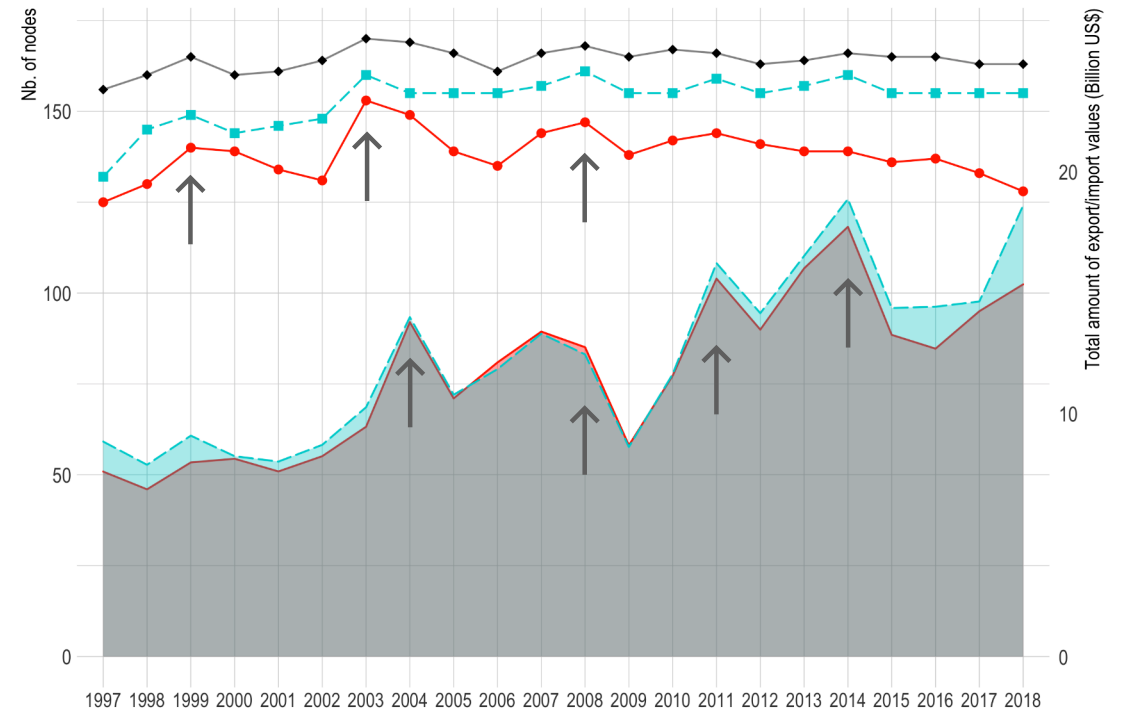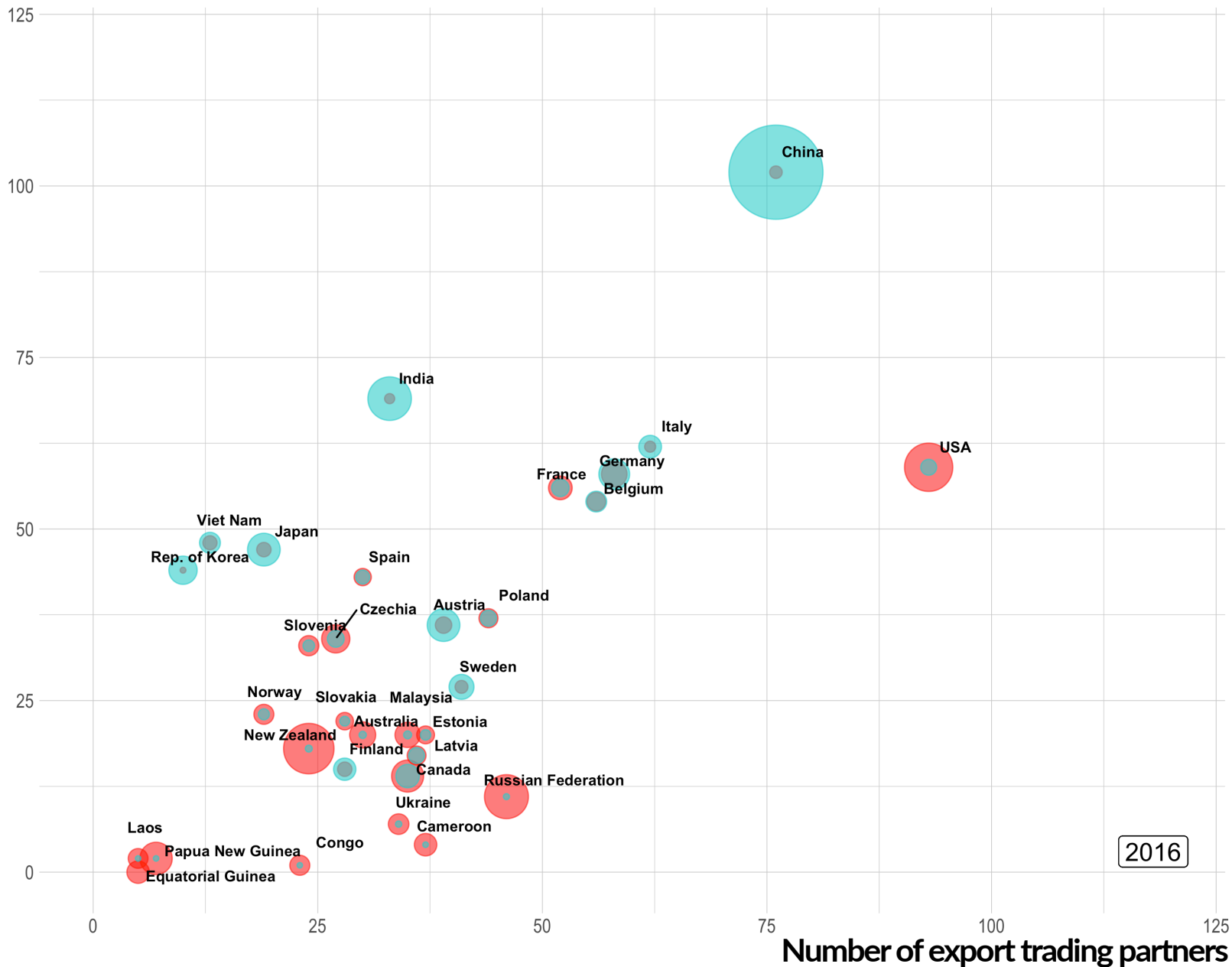
Network size and composition

Figure. Number of nodes in the network per year (lines) and reported total value of traded goods per year (billion US$, surfaces). Exports are plotted in red; imports are plotted in cyan. Total number of countries involved in trade is in black.

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Network connectedness

Mean number of connections per node provides **information on the average number of trading partners per country.**

Countries involved in trade were on average **increasingly connected** between 1997 and 2018, with **exporters being on average more connected than importers.**

We notice **several phases of increase and decrease of the mean, with sharp drops** after the financial crisis of 2008 and 2016, for instance..
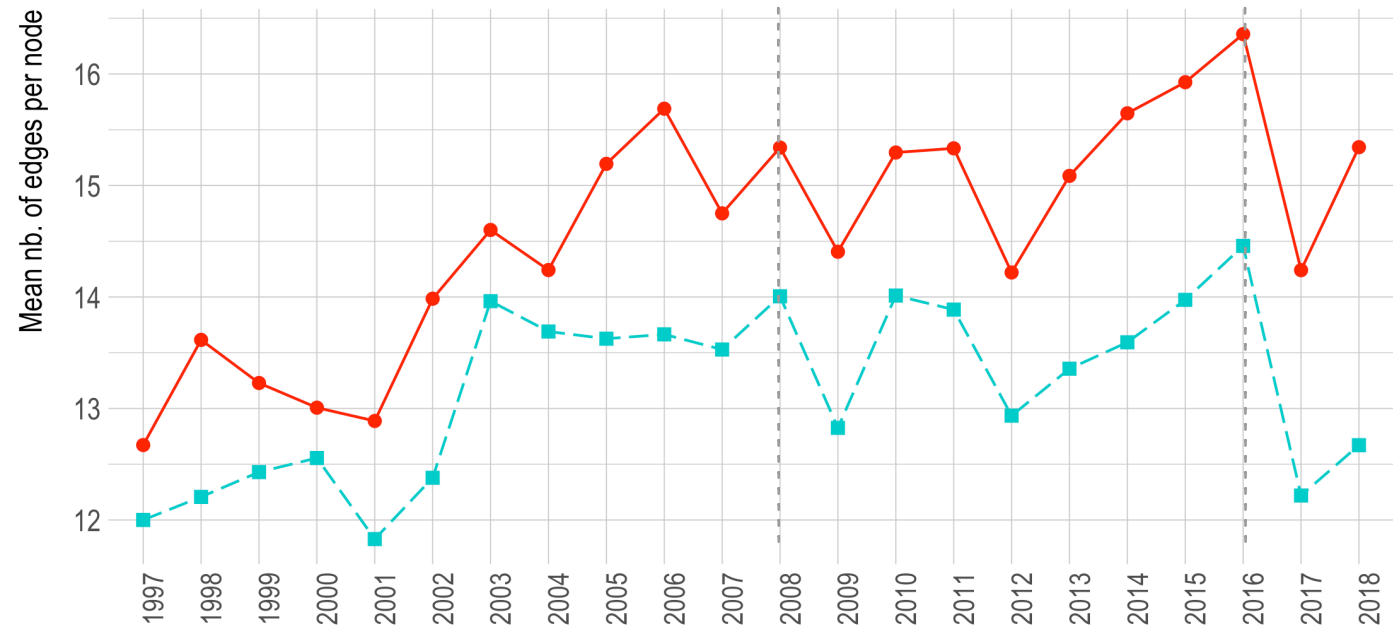

Figure. Mean number of connections per node. Means for exports are in red, means for imports are in cyan.

Network connectedness

Variance and skewness in the number of connections per node provide **information on the variation in the number of trading partners per country** relative to the mean and on **proportion of low to highly connected countries**, respectively.

Each network is comprised of **a diversity of countries** with poorly connected countries and highly connected countries, with a **greater proportion of poorly to highly connected countries**. **Proportion of poorly connected countries is higher for imports** than for exports.

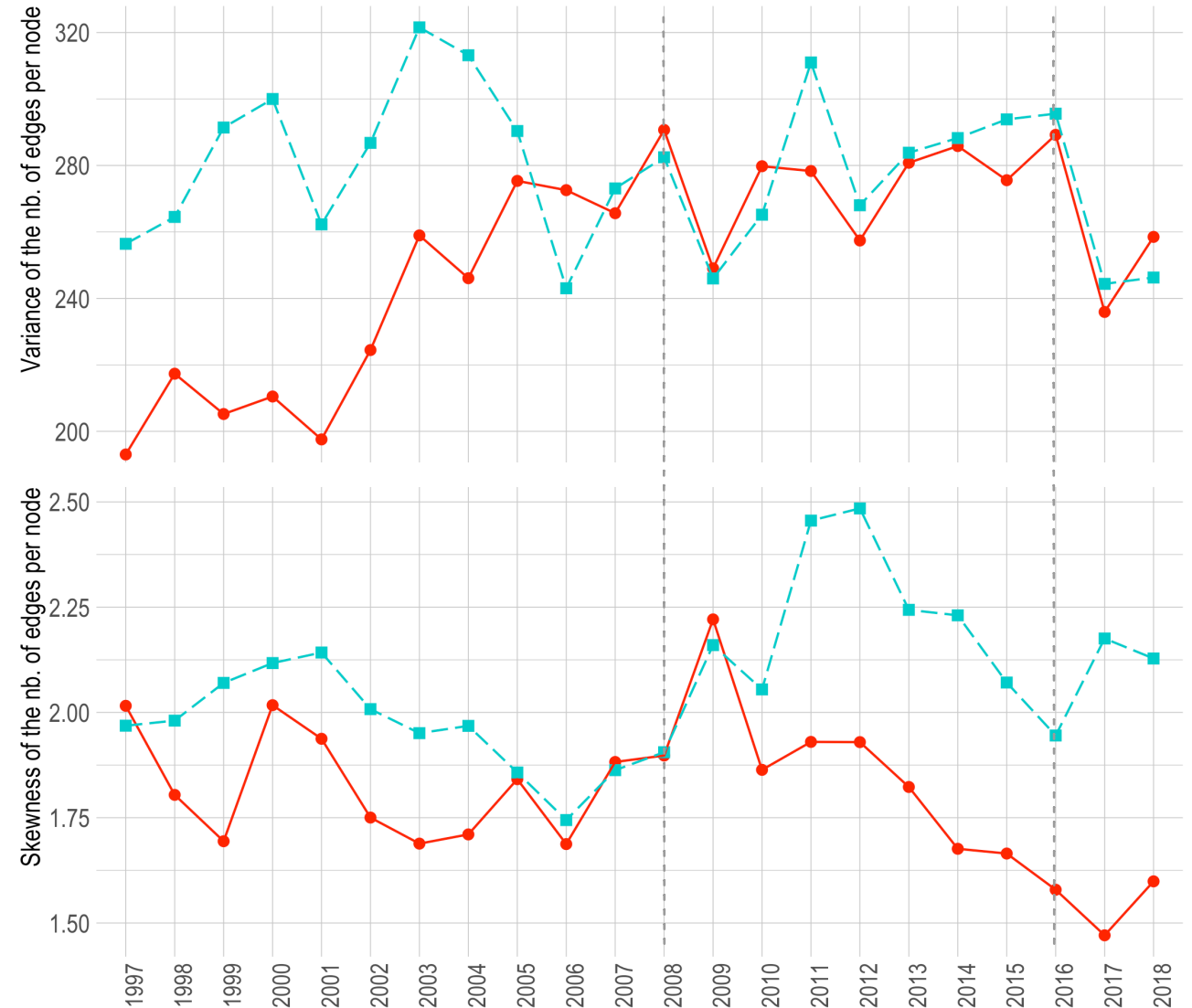We notice several phases of increase and decrease.

Figure. Variance (top) and skewness (bottom) in the number of connections per node. Metrics for exports are in red, metrics for imports are in cyan.

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How can we explain the overall increase in connectedness?

The network became more tightly connected as a result of globalization (Turner et al., 2001; Zhu et al., 2001; Devadoss and Aguiar, 2006).

Countries with high numbers of trading partners in 1997 – such as the United States and Canada, Western Europe, Scandinavia, and Russia – maintained a high number of connections for the entire study period.

A growing importance of certain countries, such as China, in the international forest products trade (Long et al., 2019; Zhou et al., 2021; Shen and Lovrić, 2022).
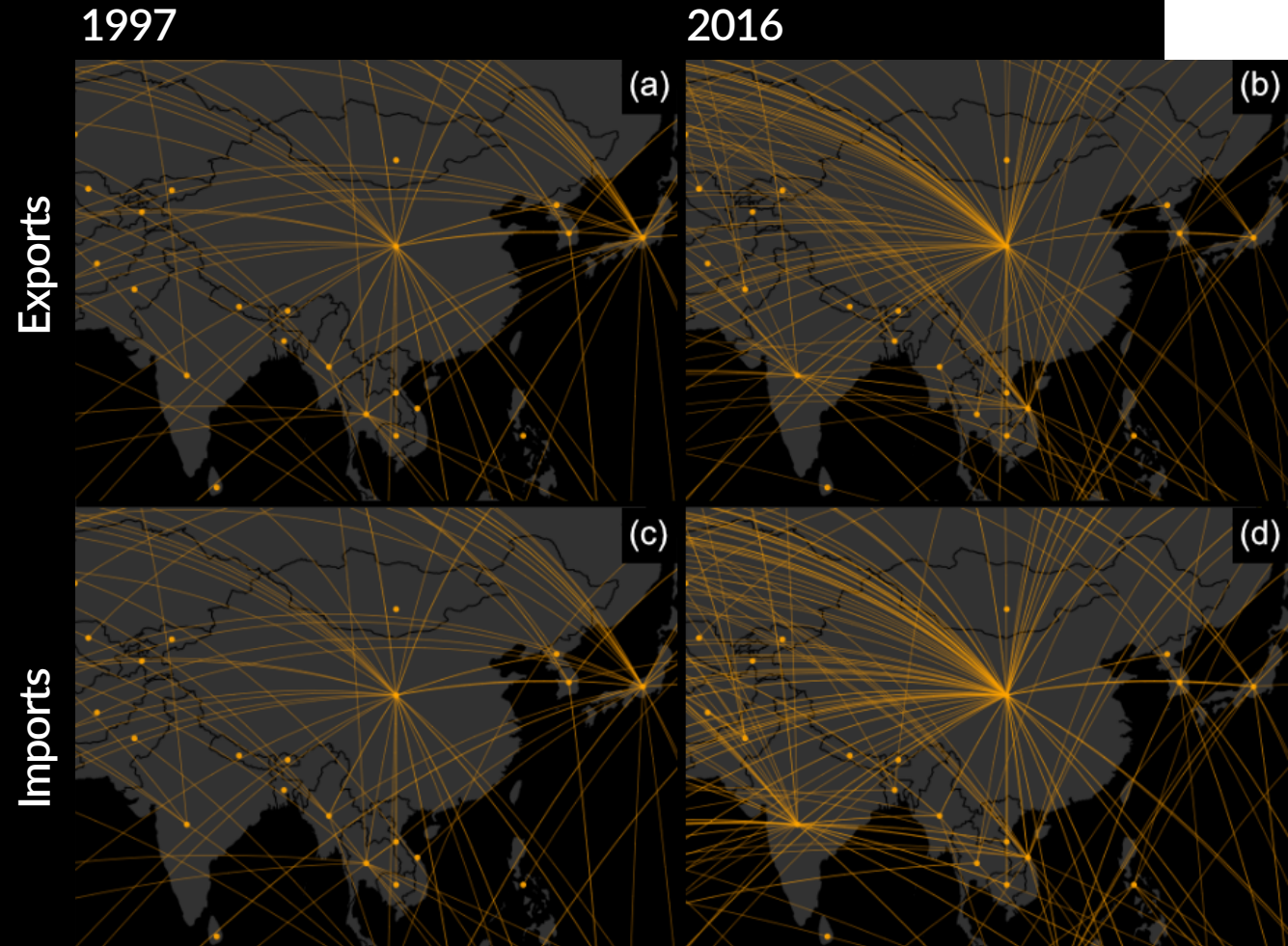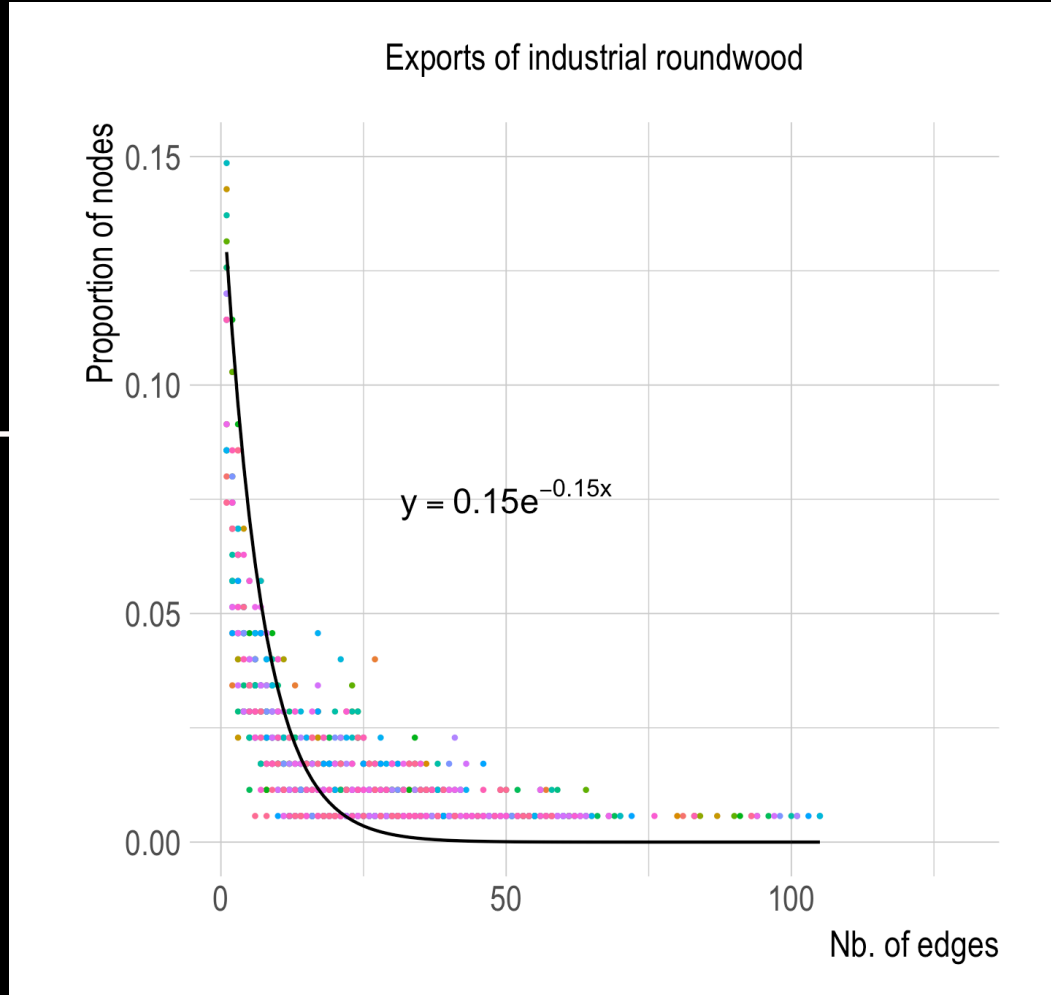

Figure. Maps of the industrial roundwood flows in part of Southeast Asia. The map only displays flows with a value greater than 1 million US$.
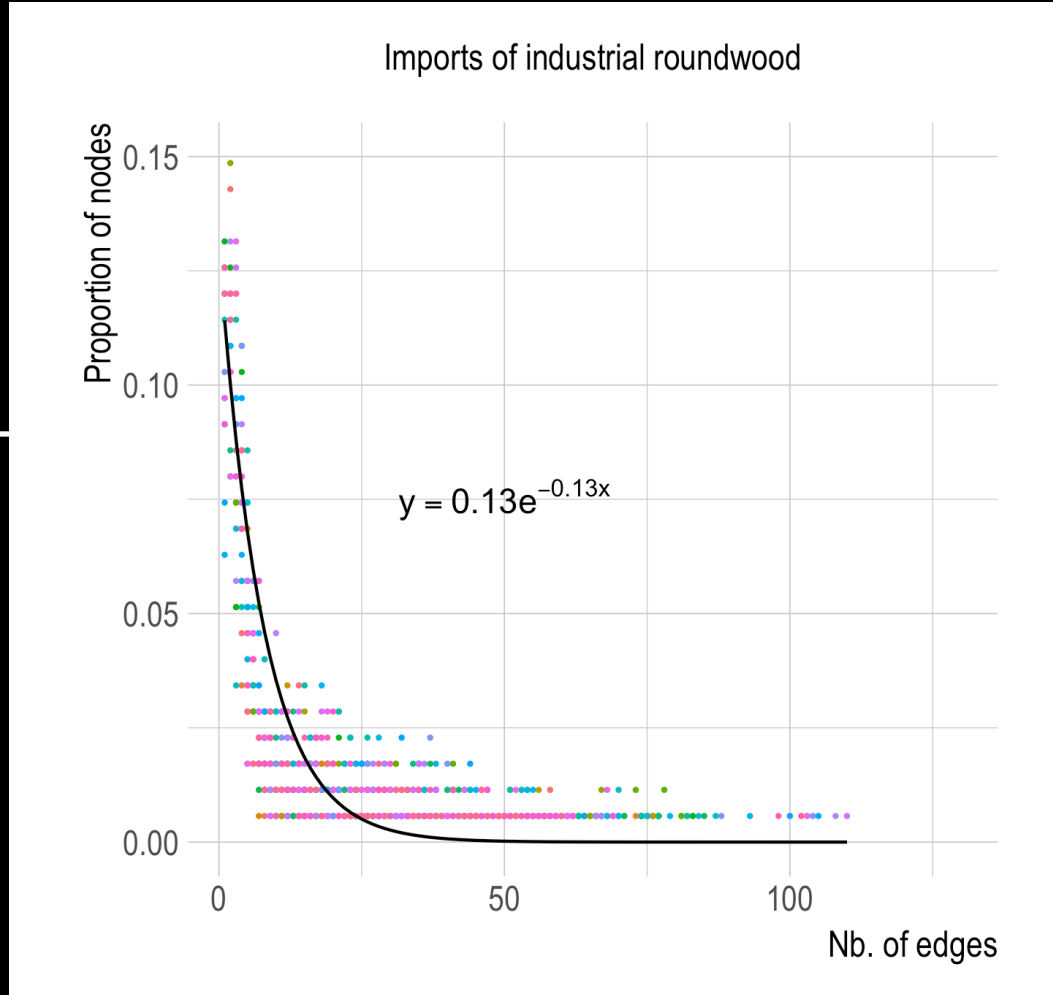
Network typology: a small-world network

Exports of industrial roundwood

$$y = 0.15e^{-0.15x}$$

Degree distribution and probability law

Provide information on the type of network we study. Here, a small-world network: new trading countries are more likely to trade with highly connected countries.

Power law or exponential distribution

Indicates a certain degree of concentration into the market. Here, a very few highly connected countries concentrate most of the trading connections.

Network typology: a small-world network

Imports of industrial roundwood

$y = 0.13e^{-0.13x}$

(Proportion of nodes vs. Nb. of edges)

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Exporters and importers behave the same

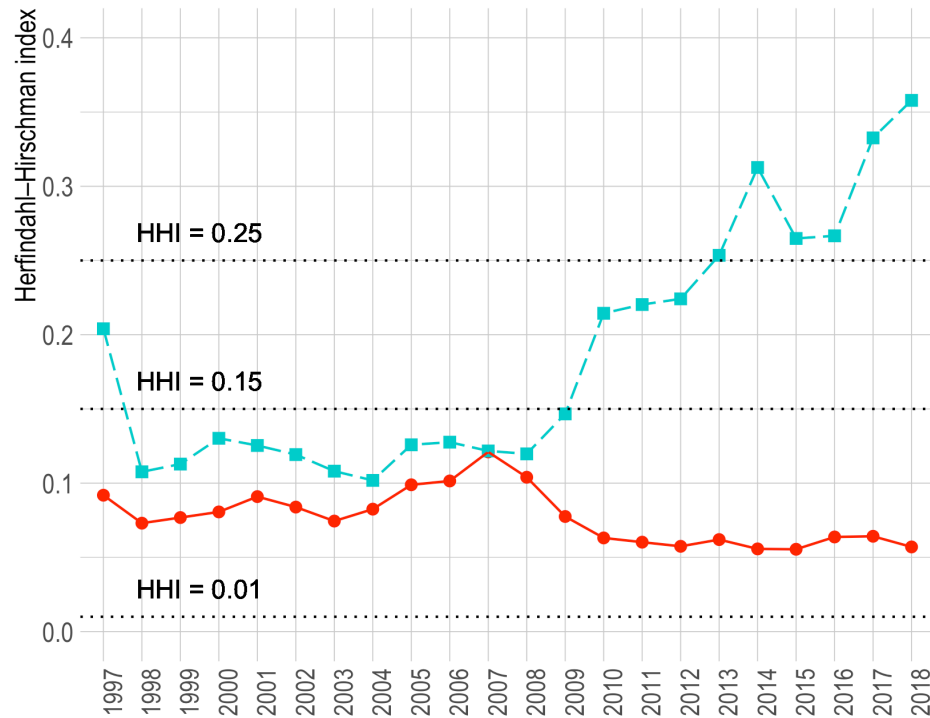Surprisingly, new importers and exporters connect in a very similar way into the network.

(a)

Figure. Herfindahl-Hirschman index over time, for exports in red, for imports in cyan.

Concentration of the global industrial roundwood trade

Imports of industrial roundwood have been **increasingly concentrated since 2009** and have been **highly concentrated since 2012**.

Exports of industrial roundwood have remained **poorly concentrated.**

04 Conclusion and takeaway messages

Takeaway messages

The global industrial roundwood trade network have **increased in value, have varied in its composition of exporters and importers, and have become more tightly connected** since 1997.

Trade network is characterized by **contrasting situations between countries**, with a few highly connected countries being at the core the network dynamics and with a greater proportion of lowly to highly connected countries.

General trends in the network result from globalization, growth in the size of the global economy, and of the **growing importance of certain countries** in the international forest products trade.

The variation in the network structure over time can be explained by three main categories of events: **economic disruptions, political events, and natural disasters.**

Exporters and importers manifest **distinct yet similar behaviors**, in relation to the polarization of the trade network.

The **polarization of the network around a few highly connected countries, especially China,** raises the question of the network's resilience to crises.

Thank you!

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