

**Master's Thesis of Engineering**

# **Dynamics of Peru's Position in the Global Copper Ore Trade: A Social Network Analysis**

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# Dynamics of Peru's Position in the Global Copper Ore Trade: A Social Network Analysis

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In an era where energy transition takes precedence, copper is a vital component, underscored by the International Energy Agency (IEA) as a critical mineral for achieving the Paris Agreement goals. Under the IEA Sustainable Development Scenario, copper demand is projected to increase by more than 40% over the next two decades, highlighting the significance of this resource for sustainable energy systems. With approximately 50% of the global copper ore production centralised in just three countries, the western part of South America, specifically Chile and Peru, dominates the sector, contributing 40% of the global supply.

This thesis delves into Peru's dynamic role within the global copper ore trade network amidst escalating demand and concentrated production. It navigates Peru's evolving export position, examines its response to shifting export values and trade partners, and evaluates its influence on the global copper ore trade network for over a decade. Through Social Network Analysis (SNA), this study reveals Peru's remarkable resilience as a leading copper ore exporter from 2013 to 2022, as illustrated by its stable normalised out-degree and high betweenness centrality, which affirms its strategic role as an intermediary and influencer in trade flows.

The findings underscore Peru's growing interconnectedness with its trade partners, bolstered by an increasing clustering coefficient, indicating robust and direct trade relationships. However, the rise of competitors, specifically Indonesia and Brazil, introduces new challenges and requires strategic adjustment. The research concludes that Peru's significant role in the global copper ore network is characterised by its adept navigation of market fluctuations and competitive pressures.

This study provides critical insights into the dynamics of the copper ore trade market for policymakers, economists, and industry stakeholders. This enriches our understanding of Peru's key

position in the global copper industry, its contributions to energy transition, and its strategic international interactions. The strategic implications highlight the necessity for diversification, strengthening diplomatic relations, and implementing risk mitigation strategies to preserve and augment Peru's status as a preeminent copper exporter. These insights and recommendations aim to guide sustainable resource management and foster resilient international trade relations in a rapidly evolving global market.

**Keywords: Copper ore, Social Network, Peru, international trade**

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# Chapter 1 Introduction

## 1.1. Background

Copper is a vital metallic element with several applications and is of significant importance in numerous domains of human existence. Copper has several applications, including electrical wires, power production, transmission systems, electronic product manufacturing, and electrical components (Doebrich, 2009; Congcong, 2010). Moreover, according to the Internacional Copper Study Group, copper is considered an environmentally sustainable resource because of its high recyclability and ability to maintain its quality during several recycling processes (ICSG, 2022). Thus, resource mining and energy conservation can be reduced. Copper is an essential element in energy transitions, as highlighted by the International Renewable Energy Agency (IRENA, 2021). According to the International Energy Agency (IEA, 2021), the demand for copper will increase by more than 40% over the next two decades, assuming a scenario aligned with the targets outlined in the Paris Agreement.

The concentration of copper deposits and production is pronounced in a limited number of nations. According to recent data from IHS Markit (2022) and the US Geological Survey (USGS, 2023), Chile and Peru collectively contribute approximately 38% of the global output of copper ore, while also holding approximately 30% of the world's total reserves of this valuable mineral resource. Prior to 2002, the determination of copper supply and demand predominantly relied on industrial production. After 2002, commonly referred to as the “China Era”, there was a notable acceleration in the demand for copper, which can be attributed to the robust economic expansion experienced by China (IHS Markit, 2022). The COVID-19 pandemic has been an unforeseen and noteworthy event in the global economy. The pandemic has significantly impacted global supply chain systems across several domains. National lockdowns can impede or temporarily halt the movement of raw resources and commodities. Additionally, the disruption of copper's international commerce resulted in the ultimate termination of the “China Era” (IHS Markit, 2022). However, copper market equilibrium remains of considerable importance, as indicated by the IEA in 2021. Hence, examining the

repercussions of the pandemic, which has the potential to induce substantial transformations in the copper trade market worldwide, presents a valuable prospect for elucidating the influence of unforeseen occurrences on the global resource trade market.

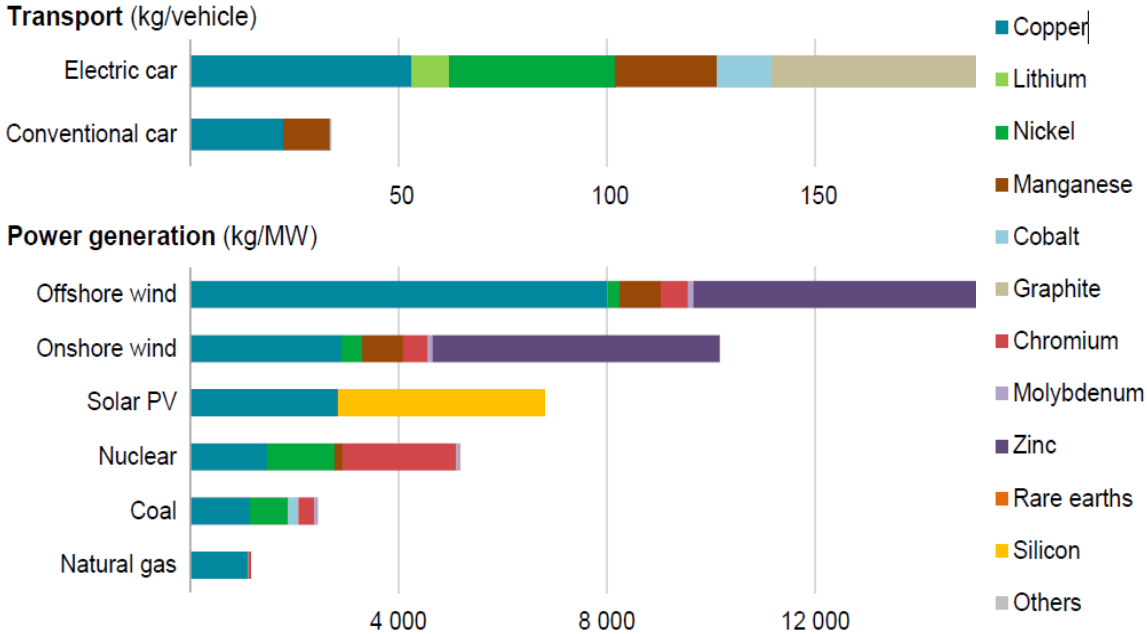
This study concentrates on the intricate web of Peru's copper ore trade within the global marketplace, emphasising the ramifications of the COVID-19 pandemic on its trading patterns and bargaining power. Previous studies (Congcong, 2010; Tong & Lifset, 2006; Kang et al., 2022) have scrutinised the export dynamics and competitive stature of nations in the copper trade; however, they have largely overlooked the intricate relational dynamics among trading nations. Moreover, the seismic disruptions spawned by the COVID-19 pandemic have injected unprecedented complexities into these global trade networks, warranting a focused investigation of their effects on copper ore trade dynamics. Previous research has not sufficiently examined how the COVID-19 pandemic has reshaped trade patterns in the copper ore sector (Goncer-Demiral and Ince-Yenilmez, 2022; Kang et al., 2022). To address this gap, this study aims to shed light on the impact of the pandemic on Peru's position in the global copper ore trade by exploring how these turbulent times have altered trade flows, relationships, and the country's standing within this critical economic sector.

The data regarding the international trade of copper ore has been acquired from the Trade Map for study. The collected data were classified annually in a ten-year timeline, from 2013 to 2022, encompassing 62–69 nations per year, representing the entire copper ore trading network. A social network analysis (SNA) methodology was employed to examine the dynamics of international commerce in copper ore and the resultant shifts in trading connections. The establishment of worldwide networks for copper ore trading involves identifying nations as individual nodes and representing the economic relationships between these countries as links. The created network was both directed and weighted. Moreover, centrality metrics, namely degree centrality, betweenness centrality, modularity, and clustering were employed to ascertain Peru's interactions in the context of international trade interactions with copper ore.

## **1.2. Problem Statement**

Copper production is a vital sector in the raw materials business, providing nonferrous metals for infrastructure construction. This requires significant energy consumption, involving mining, beneficiation, smelting, and refining stages. The rise in copper demand is expected to persist owing

to population growth, infrastructure development, and copper-dependent technologies (Dong, 2020). Electricity networks encompassing transmission and distribution systems require substantial quantities of copper and other essential minerals. The utilisation of wind and solar power in a spatially spread manner results in increased “system costs” associated with critical minerals. This is because of the need for additional power lines, storage devices, and other assets to connect and support dispersed power generation (DeWit, 2023).



*Figure 1 Minerals used in selected clean energy technologies*  
 Source: International Energy Agency (2021). *The Role of Critical Minerals in Clean Energy Transition*.  
 Page 6.

Based on this evidence, it can be inferred that the demand for copper in clean energy technologies continues to be substantial in terms of both weight and monetary value. Clean energy technologies are the most rapidly expanding sector in terms of copper consumption. According to the IEA, in 2021, the proportion of copper demand attributed to the STEPS scenario is projected to increase from its current level of 24% to 30% by 2040. This share is expected to reach 45% under the SDS scenario. The utilisation of minerals in renewable energy technologies may be exemplified by the substantial quantity of copper required during the transition to clean energy.

As noted by Muñoz (2023), the mining sector’s susceptibility to copper price fluctuations underscores the economic volatility inherent in Peru’s dependency on copper exports. Such volatility

affects Gross Domestic Product (GDP) and exchange rate stability and has significant implications for the socioeconomic fabric of mining districts, where shifts in copper prices have been linked to changes in poverty levels. This economic precarity, compounded by externalities such as commodity price changes, sets the stage for examining the broader implications of Peru’s copper trade dynamics.

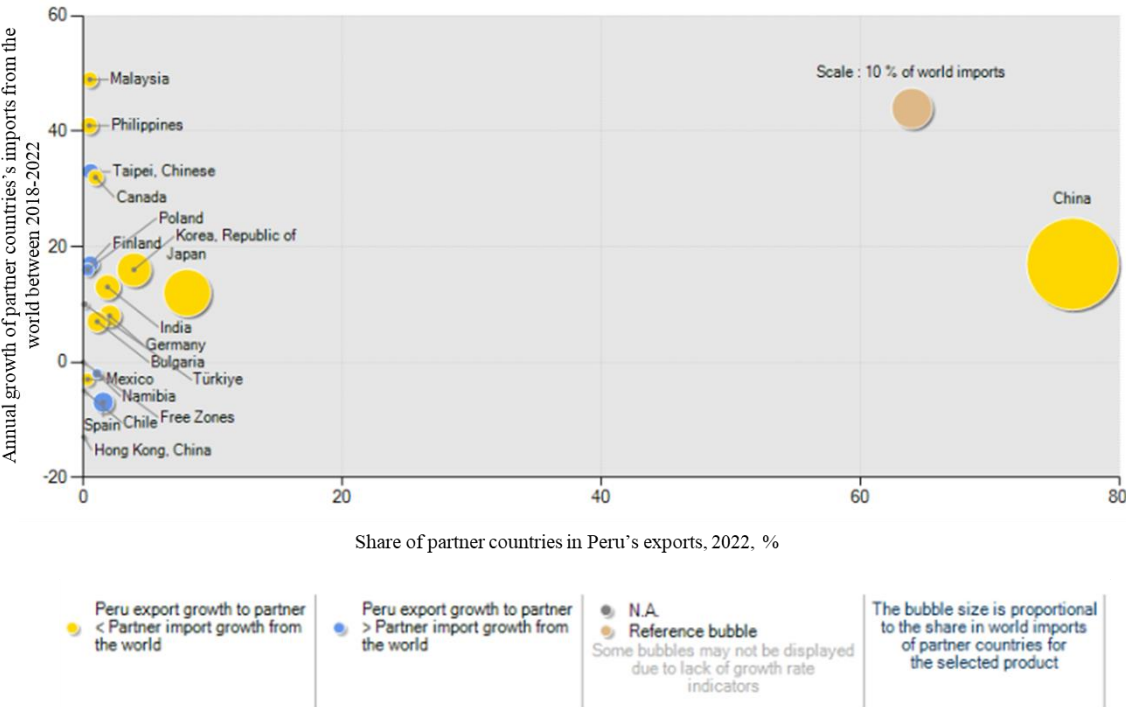


Figure 2 Copper ore and concentrates exported by Peru in 2022  
 Source: Retrieve from <https://www.trademap.org/>. June, 2023.

Further complicating the situation, the disruptions caused by the COVID-19 pandemic have brought about unprecedented supply chain challenges and heightened the unpredictability of metal futures, including copper (Melo, 2023). The pandemic’s impact has intensified the need for a more resilient and adaptable trade network, particularly in light of Peru’s heavy reliance on copper exports. Peru was one of the fastest countries in the world to announce severe measures against COVID-19, as can be seen in Table 1.

Table 1 Timeline of Legal Documents for Mining Sector Regulation During COVID-19 in Peru

Date	Description	Legal Document
------	-------------	----------------

20/03/15	Declaration of State of National Emergency.	D.S. N° 044-2020-PCM <sup>1</sup>
20/03/17	MEF approves the inclusion of the mining sector in activities exempted from the State of Emergency.	Office No. 059-2020-EF/10.1 <sup>2</sup>
20/04/03	The production of input required for the activities of the mining subsector and other related activities is included in the list of strictly indispensable additional activities that do not affect the national emergency.	R. M. N° 125-2020-PRODUCE <sup>3</sup>
20/04/15	The protocol for people mining transfer is approved.	R.M. N° 111-2020-MINEM/DM <sup>4</sup>
20/04/15	Demobilisation of Mining Units.	D.S. N°068-2020-PCM <sup>5</sup>
20/04/29	Approval of health guidelines for workers' surveillance against COVID-19, including the mining sector.	R. M. N° 239-2020-MINSA <sup>6</sup>
20/05/03	Approval of economic activities resumption in 4 phases. Large mining and national interest construction were included in the first phase.	D.S. N° 080-2020-PCM <sup>7</sup>
20/05/06	Sanitary Protocol for COVID-19 prevention in mining activities approved.	R.M. N° 128-2020- MINEM/DM <sup>8</sup>
20/05/06	Approval of 'Territorial Focalization Criteria' for large mining and construction projects of national interest.	R.M. N° 129-2020- MINEM/DM <sup>9</sup>
20/05/10	Extension of deadlines to ensure compliance with minimum production and payment of validity and penalty.	D.L. N° 1483 <sup>10</sup>
20/06/02	Approval of administrative procedures list for Mining Subsector exempt from suspension of deadlines.	R.M. N° 147-2020- MINEM/DM <sup>11</sup>
20/06/04	Phase 2 of activities resumption is approved and includes various mining activities.	D.S. N° 101-2020-PCM <sup>12</sup>

<sup>1</sup> D.S. N° 044-2020-PCM: Supreme Decree No. 044-2020-PCM, issued by the Presidency of the Council of Ministers of Peru, dated March 15, 2020.

<sup>2</sup> Office No. 059-2020-EF/10.1: Official Letter No. 059-2020-EF/10.1, issued by the Ministry of Economy and Finance of Peru, dated March 17, 2020.

<sup>3</sup> R.M. N° 125-2020-PRODUCE: Ministerial Resolution No. 125-2020-PRODUCE, issued by the Ministry of Production of Peru, dated April 3, 2020

<sup>4</sup> R.M. N° 111-2020-MINEM/DM: Ministerial Resolution No. 111-2020-MINEM/DM, issued by the Ministry of Energy and Mines of Peru, dated April 15, 2020

<sup>5</sup> D.S. N° 068-2020-PCM: Supreme Decree No. 068-2020-PCM, issued by the Presidency of the Council of Ministers of Peru, dated April 15, 2020.

<sup>6</sup> R.M. N° 239-2020-MINSA: Ministerial Resolution No. 239-2020-MINSA, issued by the Ministry of Health of Peru, dated April 29, 2020.

<sup>7</sup> D.S. N° 080-2020-PCM: Supreme Decree No. 080-2020-PCM, issued by the Presidency of the Council of Ministers of Peru, dated May 3, 2020.

<sup>8</sup> R.M. N° 128-2020- MINEM/DM: Ministerial Resolution No. 128-2020-MINEM/DM, issued by the Ministry of Energy and Mines of Peru, dated May 6, 2020.

<sup>9</sup> R.M. N° 129-2020- MINEM/DM: Ministerial Resolution No. 129-2020-MINEM/DM, issued by the Ministry of Energy and Mines of Peru, dated May 6, 2020.

<sup>10</sup> D.L. N° 1483: Legislative Decree No. 1483, issued by the Congress of the Republic, dated May 10, 2020.

<sup>11</sup> R.M. N° 147-2020- MINEM/DM: Ministerial Resolution No. 147-2020-MINEM/DM, issued by the Ministry of Energy and Mines of Peru, dated June 2, 2020.

<sup>12</sup> D.S. N° 101-2020-PCM: Supreme Decree No. 101-2020-PCM, issued by the Presidency of the Council of Ministers of Peru, dated June 4, 2020.

20/06/30	Approval of Phase 3 of the Resumption of activities. Among the mining activities are all activities corresponding to the mining sector not included in Phases 1 and 2 of the resumption of activities.	D.S. N° 117-2020-PCM <sup>13</sup>
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Cáceres added another layer of complexity by discussing the vulnerability of Peru’s copper exports to oscillations in China’s demand. Reliance on a single dominant trading partner such as China could expose the Peruvian economy to substantial risk should China’s appetite for raw commodities decrease (Caceres, 2020). shows the first destiny of copper ore and concentrates exported from Peru, with China at 60%, Japan in second rank at 5%, and then Korea at 4% (Minem, 2023), demonstrating Peru’s high export dependence on China.

The societal and environmental dimensions of copper mining in Peru were highlighted by Ratigan and Bamber et al.,. (Ratigan,2021) shed light on the public’s ambivalent perception of China’s involvement in local mining ventures, whereas (Bamber et al., 2023) argued for a robust national policy framework that integrates environmental and social considerations. They advocated the selection of a dedicated national ministry to lead the development of the mining sector, which is underpinned by stringent environmental regulations and a transparent monitoring system. These recommended reforms seek to minimise the adverse impacts of mining while fostering sustainable development, reflecting the necessity of a multidimensional approach to managing Peru’s copper ore trade.

Therefore, this thesis explores the multifaceted nature of Peru’s global position in the copper ore trade network by leveraging social network analysis to map the economic, social, and political intricacies that define its standing in the global arena. This study aims to unravel the complexities of trade relationships, national policy implications, and potential paths amid the looming challenges of market dependencies, pandemic disruptions, and future commodity scarcity, as projected by Liu et al. (2023).

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<sup>13</sup> D.S. N° 117-2020-PCM: Supreme Decree No. 117-2020-PCM, issued by the Presidency of the Council of Ministers of Peru, dated June 30, 2020.

### 1.2.1. Research Questions

In pursuit of a deeper understanding of the global copper ore trade network, this thesis aims to unravel the complexities of the evolving role of Peru in this intricate system. As the world grapples with the unprecedented economic challenges posed by the COVID-19 pandemic, assessing stability and shifts in trade dynamics has become increasingly crucial, particularly for leading commodity exporters such as Peru. The following research questions were posited to navigate through the myriad layers of trade networks, export strategies, and geopolitical interplay that shape a country's footprint in the global distribution of copper ore.

1. How has Peru's position as one of the largest exporters of copper ore evolved, and how do changes in export values and countries impact its role as an exporter within the global copper ore trade network?
2. How has Peru influenced its position and interactions with other countries over time?

### 1.2.2. Research Objective

To examine the evolving role of Peru as a prominent copper ore exporter, this thesis explores how changes in export values and trading partners impact its position within the global copper ore trade network and assesses the influence that Peru wields within the network and its consequences on its relationships with other countries over time. The research goals are summarised as follows:

1. To map and analyse the evolution of Peru's status as a leading exporter of copper ore, this study investigates trends in export values and the diversification or consolidation of trading partners.
2. To evaluate the extent of Peru's influence within the global copper ore trade network, this study examines the role of the country in shaping the network structure and its bilateral and multilateral interactions over time. This will include assessing Peru's trade activities' direct and indirect impacts on the network and its relations with other key players in the copper ore market.



### **1.3. Scope of the Study**

This study focuses on the pivotal role of Peru in the global copper ore trade network, particularly considering the heightened demand forecasted by the IEA in their Sustainable Development Scenario (SDS). This study spans a decade and aims to capture the nuances of Peru's evolving export dynamics against the backdrop of an energy transition that positions copper as a critical resource. This investigation analyses how Peru's export values and relationships with trading partners have shifted, and what implications these changes hold for its standing in the global copper ore trade network.

This study seeks to examine the transformation of Peru's status as a leading exporter of copper ore within this framework. Academic scrutiny is directed toward understanding the historical and recent trends influencing Peru's export performance. The scope includes a detailed examination of trade data to correlate fluctuations in export values and the diversification of trading partners with Peru's changing role in the market. By quantifying these elements, this study provides a comprehensive overview of Peru's export landscape over a selected period.

Employing SNA as the primary methodology, this study aims to evaluate the extent of Peru's influence on the global copper ore trade network, explore Peru's role as an intermediary or hub in the trade network, and assess the strength and nature of its linkages with other nations. The application of SNA enables multi-dimensional analysis, revealing the structural and relational aspects of Peru's position and its trajectory of interactions within the international trade community.

Ultimately, this study serves as a resource for policymakers, economists, and industry stakeholders by providing insights that can inform strategic decisions in resource management and international trade. This study aims to enhance the understanding of the economic and policy dimensions of Peru's participation in the copper market, contributing to a broader discourse on sustainable development and the country's role in the global energy transition. Thus, the scope is defined not only by its academic parameters but also by its practical implications and potential to influence future policies and economic strategies.

## 1.4. Thesis Structure

The structure of this thesis is carefully designed to decode the complex dynamics of the global copper trade, emphasising Peru's role. Chapter 1 lays out the groundwork for the study, starting with an overview that captures the essence and significance of the research. The Background section provides a digest of the existing literature on Peru's position in the copper ore trade, thus contextualising the current investigation. The Problem Statement defines the research questions and objectives and outlines the scope of the study for targeted exploration.

Chapter 2 offers a detailed literature review, highlighting copper's global economic importance, the intricacies of trade relationships, and the nuances of Peru's copper ore export history. It also discusses the role of social network analysis in understanding the trade network and establishes a basis for the subsequent analysis in this thesis.

Chapter 3 presents the methodology and data underpinning this research. This section describes the analytical methods, software, and tools employed for social network analysis and details the data requirements and assumptions, ensuring the clarity and validity of the results.

Chapter 4 presents the results and analysis, providing an overarching view of the global copper trade network before focusing on Peru's specific role. This chapter reveals the key positions and relationships within the network through various centrality measures and community structure analyses, summarising the principal insights.

Finally, Chapter 5 discusses the implications of the results and concludes the study. It connects the findings to broader policy considerations, summarises the main contributions of the research, acknowledges its limitations, and outlines recommendations for future research. This thesis is completed with a comprehensive bibliography, cataloguing the sources that informed the research

## **Chapter 2 Literature Review**

### **2.1. Review of the international importance of copper ore**

Copper, an ancient metal employed by humanity for thousands of years, stands as one of the most often utilised minerals globally (Doebrich, 2009). Copper plays a vital role in our everyday existence and holds significant importance across several industrial sectors. Additionally, it plays a substantial role in bolstering the country's economy through its support of infrastructure development and maintenance and the facilitation of trade and investment opportunities (IEA, 2021). Copper finds application in a wide range of industries, encompassing building construction, electric and electrical items, transportation equipment, roofing materials, chemical and pharmaceutical gear, as well as various alloy compositions. In recent years, the utilisation of copper in medical equipment manufacturing within the healthcare sector has gained prominence owing to its inherent antimicrobial characteristics (NMA, 2016). Moreover, copper has significant promise for prospective utilisation due to its versatility in several renewable energy applications. Copper has been identified as a viable material for several applications, including solar photovoltaic systems, wind power generation, bioenergy production, electric cars, and battery storage technologies, as stated by the International Energy Agency in 2022. The global significance and economic worth of environmentally friendly technology have led to a substantial surge in the demand for copper.

The utilisation of copper has shown a steady rise in several domains. The supply of copper has experienced a significant rise in recent decades in order to satisfy the escalating demand resulting from fast economic expansion, particularly in emerging nations (IEA, 2021). Based on data provided by the United States Geological Survey (USGS), copper ranks as the third most extensively utilized industrial metal globally, behind iron and aluminum. The utilization of refined copper on a global scale has experienced a significant increase of nearly threefold throughout the last five decades. This rise may be attributed to the expansion of several industries, including electronic and electrical goods, building construction, manufacturing machinery and tools, logistical equipment, as well as consumer and general items (ICSG, 2022). Due to this factor, there is an anticipated increase in the demand for copper, with estimates suggesting a rise

from 25 million metric tons (MMt) to around 50 MMt by the year 2035. Furthermore, this demand is expected to persist at historically high levels and expand further to reach 53 MMt by 2050, as reported by IHS Markit in 2022.

## **2.2. Review of the international copper ore trading relationships**

Since the onset of the 21st century, several researchers and authoritative institutions have delineated the global copper trade into two distinct temporal phases. Before 2002, the period commonly referred to as the 'Copper Cycle Era,' the supply and demand dynamics of copper were influenced mainly by industrial output. Nevertheless, following 2002, known as the 'China Era,' the demand for copper experienced a notable acceleration, aligning with the economic growth observed in China (IHS Markit, 2022). China has established itself as a prominent nation in the global copper ore trade over both periods. China's substantial and robust demand for copper has played a significant role in the increase of both global copper trade volume and global copper prices (Wang et al., 2023; Dordević et al., 2019). Moreover, it is worth noting that the U.S. market notably impacts copper's trading patterns and price fluctuations in China. This influence stems from the prominent role played by the U.S. copper futures market in disseminating information to its Chinese counterpart (Yin and Han, 2013). Nevertheless, there is a shortage of extensive studies on the demand for copper in the United States and its consequential effects on global trade patterns. Furthermore, it is worth noting that China has established a prominent position in the field of copper mining and commerce. Moreover, there has been a substantial rise in global copper mine output in recent years (Stuermer, 2022). The rise in copper use can be attributed to the increasing need for this metal in diverse industries such as building, electronics, and renewable energy.

In their study, (De Benedictis and Tajoli, 2011) conducted a comparative analysis of the temporal evolution of the global trade network's structure, focusing on identifying distinct trade patterns shown by various nations. This study offers significant contributions to understanding the evolving dynamics of global copper trade relationships. It highlights the increasing interconnectedness of the World Trade Network, accompanied by a greater diversity among countries involved. Additionally, it observes fluctuations in the average structural network distance, which initially decreases and then increases. Moreover, the study identifies shifts in the positioning of numerous countries within the network between 1950 and 2000. The worldwide commerce of copper

ore and copper products has been observed across the global value chain. Based on worldwide data, it has been determined that Chile possesses the most significant concentration of copper mining activities, while China stands as the foremost user and producer of refined copper (USGS, 2023; ICSG 2022). Between 1990 and 2015, China engaged in trade with a total of 183 nations concerning copper-containing commodities. Notably, the country imported a significant proportion of primary copper products, amounting to 99%, exclusively from Chile (Hao, 2023). China sourced a significant portion of its copper raw materials from nations abundant in copper mineral resources, such as Chile, Peru, Australia, Kazakhstan, Mongolia, and the United States, in 2015 (Hanni and Podestá, 2019). Until 2017, the United States served as a notable provider of copper concentrate to China. Nevertheless, the strained ties between China and the United States have effectively impeded the flow of commerce between the two nations, prompting alterations in the dynamics of global copper trading partnerships (Li et al., 2023). An illustration of this would be a potential tariff dispute between the two nations, which has the potential to induce volatility in copper prices. Consequently, this might have repercussions on global purchasing patterns and trade dynamics. Countries that rely on copper trade may therefore endeavor to find other suppliers or markets in order to mitigate their susceptibility to risks associated with tariffs, potentially resulting in a restructuring of trade dynamics.

However, there is also other points to take into consideration when evaluating the copper ore international market variables. Commodity prices have experienced increased volatility in recent years due to the “financialization of commodities” phenomenon and increased investment in commodity markets. This volatility impacts industries, countries, and investors. Economic variables, such as excess demand for copper and convenience yields, and financial variables like returns on the S&P 500 index, gold, oil, and commodity currencies, help predict future copper volatility (Díaz et al., 2021). One of the most important macroeconomic effect in the copper ore market is the secondary market. Since 2002, China has become the world's largest copper consumer (Doe, 2021). The proportion of Chinese copper consumption in global copper consumption has increased from 17% (2.6 million tons) in 2002 to 46% (8.4 million tons) in 2016 (Dong et al., 2019). Actually, China has implemented several policies to improve the environmental performance of its copper industry since 2013, one of which is to increase the number of inspections and restrict the import of low-quality copper scrap: the so-called “Green Fence” policy (State Council of China, 2013). The decision on whether or not to continue to import copper scrap will undoubtedly affect the future development of China's copper industry, and because of its sheer size consequently the global picture as well. It is

therefore important to explore what impact this “Green Fence” policy will have on Chinese copper supply and how Chinese copper demand will be met (Dong, et al., 2020).

Worldwide, Chile and Peru are the leading producers of copper ore. The mining heritage of Chile predates that of Peru. The smaller Chile Minerals Act has been impacted by this phenomenon, indicating that in order to maintain the same level of mineral production, Chile must increase its rock processing, resulting in reduced competitiveness (Guevara, 2018). Regrettably, an unforeseen circumstance known as the COVID-19 pandemic has emerged inside the global economy. The pandemic has profoundly impacted nearly all facets of the worldwide supply chain networks. The implementation of national lockdowns has notably impacted the pace of raw materials and commodities movement, leading to deceleration or temporary cessation. The international commerce of copper was significantly affected, leading to the conclusion of the 'China Era' (IHS Markit, 2022).

### **2.3. Review of Peru’s copper ore exports**

Peru places considerable significance on mining exports, as they constitute a substantial portion of the overall domestic export volume. In a retrospective examination spanning a decade, an average of US\$28,022 million, corresponding to 59.8% of the aggregate value of exports. It is noteworthy to acknowledge that Peru has a prominent position in worldwide and Latin American mineral production and reserves. This is attributed to its extensive range of minerals, encompassing copper, gold, and zinc (MINEM, 2023). Upon analyzing the contribution of the primary export metals, it is evident that copper ore holds the most prominent part, accounting for 29.8% of the whole quantity shipped worldwide (MINEM, 2023).

Peru, the second-largest copper producer in Latin America, has experienced fluctuations in recent years due to its proximity to Chile and global standing in red metal output. In 2016, Peru surpassed China, the United States, and Australia, becoming the second-largest producer. The country's low production costs, with many mines reporting cash costs below USD\$1 per pound, have contributed to its significant increase in copper output. With a typical global quotation of USD\$2.90 per pound in the first half of 2019, Peru's copper projects are attractive to corporations (De Echave, 2020). Even when Peru also participates in the smelting and refining process of copper, in this research we will focus only on the copper ore exports Figure 3 Copper and copper product processing.

From 1917 to 2017, the Peruvian economy exhibited a strong dependence on the production of copper, with exports playing a crucial role as a determining factor. Copper production plays a pivotal role as a determining variable in the Peruvian economy, with a firm reliance on copper exports. (Pimentel, 2019). The degree of Peru's reliance on China for copper exports surpasses that of other Latin American nations. Notably, most of these exports, above 50 per cent, are directed toward China, amplifying this particular resource's economic significance for the Peruvian economy (Casanova et al., 2016).

Furthermore, Peru is experiencing significant growth in demand due to its role as the second-largest producer. This demand is expected to meet the growing global population, projected to exceed 11 billion. However, the increased demand could lead to higher costs and reduced competitiveness for industries heavily reliant on copper. To address this, Peru should develop a copper production strategy that aligns with its goals and implement tax policies to enhance the tax collecting system (Larios-Meño et al., 2021). However, in 2022, there was a marginal decrease of 0.3% in the export volume of significant metal mining commodities compared to the preceding year. This loss may be attributed to the imposition of COVID-19-related limitations in China, as well as the decrease in the international market prices of primary metals. The industrial sector had a notable increase in interannual exports of copper, with a growth rate of 8.0% (MINEM, 2023).

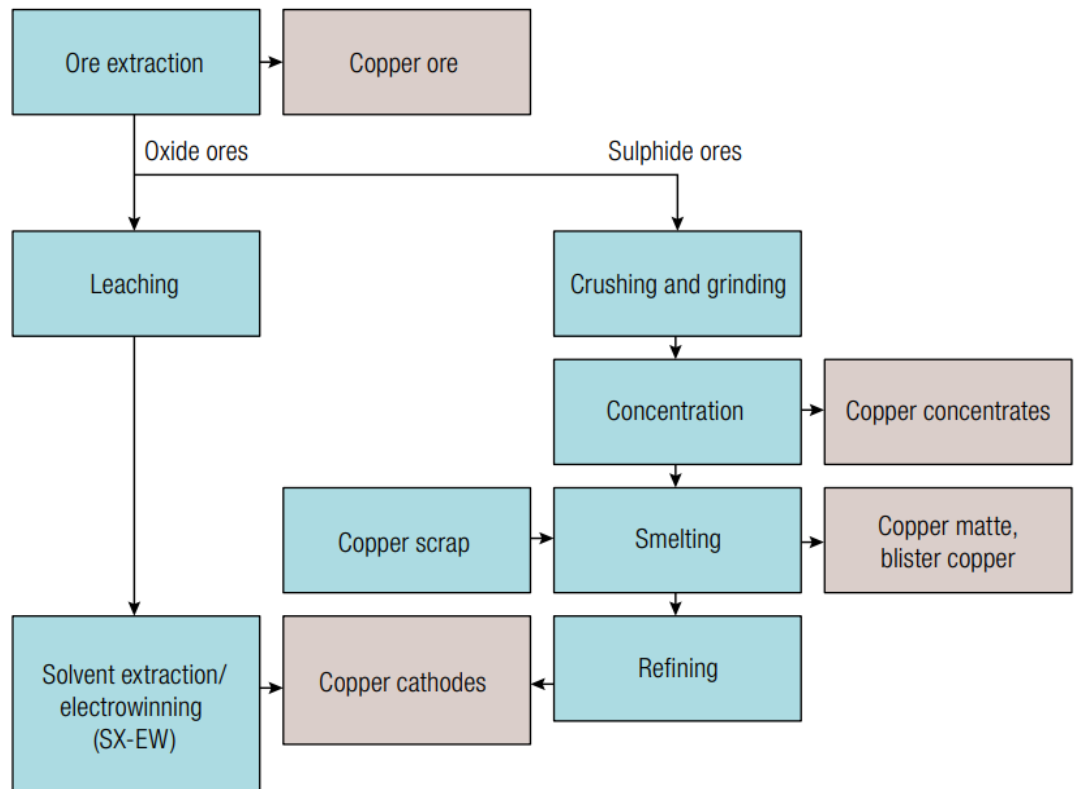


Figure 3 Copper and copper product processing

Source: Hanni, M., & Podestá, A. (2019). Trade misinvoicing in copper products: a case study of Chile and. Page 93.

## 2.4. Review of Social Network Analysis in the copper ore network

Social network analysis (SNA) is a methodology employed to investigate the social structures and interactions that exist among various entities, such as individuals, groups, companies, or even nations, inside specific systems (Wasserman and Faust, 1994). By employing network mapping techniques, it becomes possible to discern prominent individuals or organizations inside a given network and capture noteworthy interactions across diverse stakeholders (Cross and Prusak, 2002). The use of social network analysis spans across several domains, since it facilitates the comprehension of social dynamics, the diffusion of innovation, organizational and individual behaviors, the flow of resources, and the dissemination of illnesses or information within a given system (Kumar and Sinha, 2021).



Numerous academics have undertaken investigations into the phenomenon of international resource trade, utilizing social network analysis as a methodology to discern the position or prestige of nations and the patterns of trade within global systems. Nations were often classified as nodes, while the economic connections established between nations were regarded as links, forming the foundation of an international commerce network. Goncer conducted a research that analyzed the copper trade flows of the top 50 nations with the highest export volumes in 2019 and 2020 (Goncer-Demiral and Ince-Yenilmez, 2022). The findings of this study indicate that nations characterized by elevated levels of exports tend to have a propensity for engaging in trade with particular partner countries. Furthermore, it is worth noting that business relationships have been unaffected by global crises, such as economic downturns, and the ongoing epidemic, which have the potential to impact nations internationally. The findings of this study indicate that the trade network had characteristics of scale-free qualities, and the network structure was characterized by heterogeneity.

A separate investigation was conducted to analyze the global trade network of copper ore in 2009 (Congcong, 2010). The study revealed that South Africa, Peru, the United States, Chile, and Brazil were the primary exporting countries exhibiting substantial negotiation leverage. Simultaneously, with extensive trading networks, China, Korea, Germany, Spain, and Japan were widely acknowledged as prominent importers. The findings of this study indicate that South Africa and the USA have demonstrated strong negotiating power via the maintenance of existing trade connections. Additionally, the study suggests that Chile, Indonesia, Australia, and Japan have the potential to enhance their bargaining positions by cultivating additional trade partnerships.

The third research examined the copper flows within the entire industrial chain, considering the life cycle viewpoint (Kang et al., 2022). This study demonstrated that the trade competition network accurately reflects the distinctive features of regional groupings and reveals a persistent escalation of competitive tensions across various global areas. The distribution of trade rivalry exhibits unevenness, primarily observed across European and Asian nations and between individual countries within these regions. Developed nations, like Britain, Korea, and the United States, emerge as prominent contenders in pursuing copper resources. Li et al. (2021) conducted a research that examined the supply chain dynamics of copper trade, emphasizing the significance of comprehending the global copper materials trade network from an industrial chain standpoint. This process facilitates the identification of possible hazards and vulnerabilities within the sector.

Wang et al. (2020) conducted a study to investigate the dynamics of the global scrap copper trade and the temporal-spatial evolution of the community structure. From 1988 to 2017, they provided valuable insights into the worldwide trade of scrap copper on a significant scale. The America-Asia community, primarily led by the United States and China, is the most significant trade partnership in the world. China is the primary beneficiary of scrap copper owing to its limited self-reliance in terms of copper and scrap copper reserves. India is perceived as a promising market for exporters, offering long-term promise and the opportunity to diversify their reliance on a single market, such as China.

Several previous studies have examined the dynamics of resource allocation in the context of international commerce and the subsequent shifts in power dynamics and global standing. According to other study conducted, it was observed that nations tend to enhance the variety of their trading alliances and broaden the scope of their trade by engaging in the international iron flow network (Zhong et al., 2018). Nevertheless, the studies as mentioned above failed to address Peru's trading dynamics of copper ore. Therefore, the present study aims to address this research gap by examining not only previous years of the COVID-19 pandemic but also this phenomenon's impact on the copper ore trading patterns. To examine the intricacies of the copper ore trade, the present study aims to elucidate the operations of copper ore trading entities within global networks and ascertain the extent to which the pandemic has influenced alterations in copper ore trading networks.

## Chapter 3 Methodology and Data

### 3.1. Methodology

In selecting Social Network Analysis (SNA) as the primary methodology for my thesis, I aimed to capture the intricate dynamics of Peru's role in the global copper ore trade network. SNA stood out as the most fitting approach for several reasons:

1. **Capability to Map Complex Relationships:** SNA's strength lies in its ability to visually and quantitatively map complex relationships and interactions within a network. This capability was essential for my study, which aimed to explore the evolving role of Peru and its interactions with various trading partners. Through SNA, I could effectively visualize and quantify these relationships, offering a detailed understanding of Peru's position within the network and its changes over time.
2. **Quantitative and Qualitative Insights:** The dual capacity of SNA to provide both quantitative data about the network and qualitative insights into the nature of connections proved invaluable. It enabled a comprehensive analysis of the direct and indirect impacts of Peru's trade activities within the global copper ore trade network, aligning perfectly with my research goals.
3. **Tracking the Evolution of Trading Relationships:** My research focuses on examining the diversification or consolidation of Peru's trading partners over a decade. SNA is uniquely suited to track and analyze the evolution of these relationships over time, offering a dynamic perspective on the network and showing how Peru's connections have evolved in response to various factors.
4. **Assessing Influence and Role within the Network:** A critical aspect of my study is evaluating Peru's influence within the network. SNA is adept at identifying key players and their levels of influence using metrics like betweenness centrality, degree centrality, and closeness centrality. This quantitative measure of Peru's influence is integral to understanding its role in the network.

Indeed, there are other quantitative methods that can be used for similar approaches. The most alike are Time Series Analysis and Econometric Modeling. In the following chart, there is summary about the strengths and weaknesses for each methodology:

Table 2 Methodology's comparison

Methodology	Strengths	Weaknesses
Time Series Analysis	<ul style="list-style-type: none"> <li>• Effective for identifying trends and patterns over time.</li> <li>• Useful for forecasting future trends based on historical data.</li> <li>• Can reveal cyclical and seasonal variations in Peru's copper exports.</li> </ul>	<ul style="list-style-type: none"> <li>• Primarily univariate, focusing on a single variable over time.</li> <li>• Limited in addressing the complexity of network relationships.</li> <li>• Does not provide insights into the nature of relationships or network structure.</li> </ul>
Econometric Modeling	<ul style="list-style-type: none"> <li>• Allows for the quantification of relationships between multiple economic variables.</li> <li>• Can assess the impact of external factors like global market trends on Peru's exports.</li> <li>• Useful for hypothesis testing and causal inference.</li> </ul>	<ul style="list-style-type: none"> <li>• Requires a strong theoretical basis for model specification.</li> <li>• Results can be sensitive to model assumptions.</li> <li>• May not capture the non-linear and dynamic nature of trade networks.</li> </ul>
Social Network Analysis	<ul style="list-style-type: none"> <li>• Ideal for mapping and analyzing complex relationships in a network.</li> <li>• Provides both qualitative and quantitative insights.</li> <li>• Can identify key players and measure influence within the network.</li> </ul>	<ul style="list-style-type: none"> <li>• Data-intensive, requiring detailed information on network connections.</li> <li>• Less focused on external economic factors impacting the network.</li> <li>• Can be complex to interpret and require specialized software.</li> </ul>

In order to examine the intricacies of copper ore trade interactions and identify significant participants in the international market, two distinct centrality measures—degree centrality and

betweenness centrality—were implemented for a specified duration. Centrality quantifies the degree to which a specific node is critical to the operation of a network. The degree centrality metric is employed to discern several influential nations within the global copper ore trade network. By calculating the degree centrality of a node, which indicates the number of direct connections it has within the network, its strength within the network may be determined (Lee et al., 2021). The measurement of in-degree centrality and out-degree centrality is distinct in directed networks due to the fact that the significance of the links' direction varies. The countries that import copper ore are identified by in-degree centrality, which might provide an explanation for their reliance on countries that export copper ore. Conversely, out-degree centrality discerns the identities of the exporters inside the network, so illuminating the quantity and number of nations to which copper ore exporters distribute their goods.

The following equations are utilized to calculate degree centrality (DC) and weighted degree centrality (WDC) (Newman 2005):

*Equation 1*

$$DC(v_i) = \sum_{j=1}^n a(v_i, v_j)$$

If  $v_j$  denotes all other nations,  $v_i$  signifies the focal country, and  $n$  signifies the network's total number of countries. The adjacency matrix is denoted by  $a$ , where cell  $a(v_i, v_j)$  is assigned the value one if a nation  $v_i$  is related to a country  $v_j$ , and 0 otherwise.

*Equation 2*

$$WDC(v_i) = \sum_{j=1}^n w(v_i, v_j)$$

where  $w$  represents the adjacency matrix with weights. In the event that the focal country  $v_i$  is linked to another country  $v_j$ , the weight of the link is denoted by  $w(v_i, v_j)$ . Therefore, the weighted degree centrality of node  $v_i$  is determined by adding the weights of all the links that are connected to node  $v_i$  as the goal.

The in-degree centrality of a node  $v_i$  in weighted directed networks is calculated by adding the weights of the links that descend to  $v_i$ . Conversely, the out-degree centrality of a node  $v_i$  is

determined by adding the weights of the links that originate from  $v_i$ . The following equations (Freeman 1978; Lee et al., 2021) are utilized to compute in-degree centrality ( $WDC_{in}$ ) and out-degree centrality ( $WDC_{out}$ ).

*Equation 3*

$$WDC_{in}(v_i) = \sum_{j=1}^n X_{v_j v_i}$$

where  $v_i$  is the focal country,  $v_j$  is a country exporting copper ore to country  $v_i$ , and  $X_{v_j v_i}$  represents the number of weighted links from  $v_j$  to  $v_i$ .

*Equation 4*

$$WDC_{out}(v_i) = \sum_{k=1}^n X_{v_i v_k}$$

where  $v_k$  is a country importing copper ore from country  $v_i$  and  $X_{v_i v_k}$  means the number of weighted links from  $v_i$  to  $v_k$ .

The application of betweenness centrality identifies nations that hold strategically significant locations within the global copper commerce network. Betweenness centrality is a metric that quantifies the extent to which a specific node functions as a network gatekeeper or broker (Goncer-Demiral and Ince-Yenilmez 2022). Countries that possess a high degree of betweenness centrality in a trade network are typically able to exert control over trade dynamics, improve their access to markets, smooth negotiations, and promote efficient interactions among other nations (Borgatti and Everett 2006). Countries that serve as intermediates in global trade networks can substantially influence the trade of copper ore and trading patterns within this environment. Betweenness centrality quantifies the degree to which a specific node is positioned midway across the network in relation to the other nodes, as determined by the shortest pathways (geodesics). The following are the equations (Borgatti, 2005):

*Equation 5*

$$BC(v_i) = \sum_{j,k} \frac{g(v_j, v_i, v_k)}{g(v_j, v_k)}, \quad i \neq j \neq k$$

where  $g(v_j, v_k)$  is the number of shortest paths from node  $v_j$  to node  $v_k$ , and  $g(v_j, v_i, v_k)$  represents the number of shortest paths from node  $v_j$  to node  $v_k$  that pass through node  $v_i$ .

*Equation 6*

$$WBC(v_i) = \sum_{j,k} \frac{g^w(v_j, v_i, v_k)}{g^w(v_j, v_k)}, \quad i \neq j \neq k$$

where  $g^w(v_j, v_k)$  is the number of weighted shortest paths from node  $v_j$  to node  $v_k$ , and  $g^w(v_j, v_i, v_k)$  means the number of weighted shortest paths from node  $v_j$  to node  $v_k$  that go through node  $v_i$ .

In addition to degree and betweenness centrality, this study employs modularity and clustering coefficients to understand the structure of the copper ore trade network more deeply.

Modularity is used to measure the strength of the division of a network into modules (also called clusters, groups, or communities). In the copper trade network context, a high modularity would indicate that the network is divided into clusters with dense connections internally and sparser connections between the clusters. Modularity is crucial for understanding the compartmentalization of the network, which can signal specialization or strategic trade alliances within the global copper ore trade. The modularity  $Q$  of a network can be calculated using the equation (Newman and Girvan, 2004):

$$Q = \frac{1}{2m} \sum_{ij} \left| A_{ij} - \frac{k_i k_j}{2m} \right| \delta(c_i, c_j)$$

where  $A_{ij}$  represents the edge weight between nodes  $i$  and  $j$ ,  $k_i$  and  $k_j$  are the sum of the weights of the edges attached to nodes  $i$  and  $j$ ,  $m$  is the sum of all of the edge weights in the network,  $c_i$  and  $c_j$  are the communities of the nodes, and  $\delta$  is the Kronecker delta function, which is 1 if  $c_i = c_j$  and 0 otherwise.

Clustering coefficient measures the degree to which nodes in a network tend to cluster together. Economically, this can reflect the interconnectedness of countries in trade relationships, indicating a tendency to form trade blocs or agreements. For a given node  $i$ , the local clustering coefficient  $C_i$  is defined as the following equation (Watts and Strogatz, 1998):

$$C_i = \frac{2T_i}{k_i(k_i - 1)}$$

where  $T_i$  is the number of triangles through node  $i$  and  $k_i$  is the degree of node  $i$ . For directed networks, this formula can be adjusted to account for the directionality of the relationships.

Community detection is utilized to identify the existence of communities within the network, which are groups of nodes that are more densely connected internally than with the rest of the network. In the global copper ore trade network, such communities might correspond to groups of countries that have formed strong trade alliances or have similar trade patterns. The most common method for community detection is the optimization of the network's modularity.

The Louvain method is used for community detection, an algorithm that iteratively groups the network into communities to maximize the modularity score. This method will be applied to the trade network data to identify distinct communities within the global copper ore trade.

### **3.2. Analysis software and tools**

The sophisticated analysis in this thesis on the dynamics of Peru's position within the global copper ore trade network is underpinned by the adept use of Gephi 0.10.1, a leading open-source network analysis and visualization tool. Grandjean's introduction to network analysis and visualization with Gephi highlights its utility as a user-friendly yet powerful tool that allows researchers to view data from fresh perspectives, which is especially pertinent for the intricate datasets involved in this study (Martin Grandjean, 2015). The tool is particularly beneficial for its ease of access and ability to handle two complementary datasets, which in the context of this thesis, aligns with the multi-year span and the vast array of international trade connections.

To effectively decipher the copper ore network's intricacies, Gephi's capacity for spatializing data plays a crucial role. It uses algorithms like Fruchterman Reingold for positioning nodes in a manner that is reflective of gravitational forces, aiding in the visualization of community structures within the network.

A core component of the analysis includes applying Gephi's modularity feature to detect communities, offering a window into the network's substructures. This is complemented by centrality



measures, such as betweenness centrality, that provide insight into the pivotal roles certain nations hold within the network, potentially serving as gatekeepers or bridges in the trade of copper ore. The Geo Layout plugin is leveraged to incorporate geographical coordinates, ensuring that the nodes are positioned in a way that reflects their real-world locations, thus providing a geo-spatial dimension to the network analysis.

The datasets obtained from Trade Map were preprocessed and formatted to be seamlessly integrated into Gephi, ensuring the network's directed and weighted properties are accurately represented. The data is classified annually, capturing the network's dynamism as it evolves year by year. The analysis also involves customizing the visual output based on various network measures, such as adjusting node sizes according to their degree. This is central to understanding the influence and connectivity of the different nations within the network.

In sum, Gephi 0.10.1 serves as an indispensable tool in this research, enabling the transformation of complex trade data into comprehensible and analyzable visual formats. The software's modular approach to network analysis, along with its extensive range of plugins and features, allows for a multi-faceted exploration of the global copper ore trade network, explicitly focusing on discerning Peru's evolving role within this international economic landscape.

### **3.3. Methodology Framework**

The methodology framework of this thesis is built upon a structured, multi-step approach designed to analyze social networks within the context of copper ore exports. As Figure 4 Methodology Framework shows, the process begins with a Literature Review, where existing academic and industry-specific texts are scrutinized to establish a foundation of knowledge and identify gaps that the current research aims to fill. Subsequent to the literature review is Data Collection, which involves gathering quantitative and qualitative data pertinent to the exportation dynamics of copper ore, with a particular focus on Peru's role in the global market.

With the data in hand, the framework advances to the Social Network Analysis using Gephi 0.10.1, a sophisticated software for network data visualization and analysis. The process then moves to the Revision and Upload phase, where data is verified and refined before being incorporated into the analytical framework. This step ensures the reliability and validity of the analysis. Then, the

network is conceptualized as weighted and directed, meaning that not all connections are equal, and they have a specific direction that signifies the flow of exports from source to target countries.

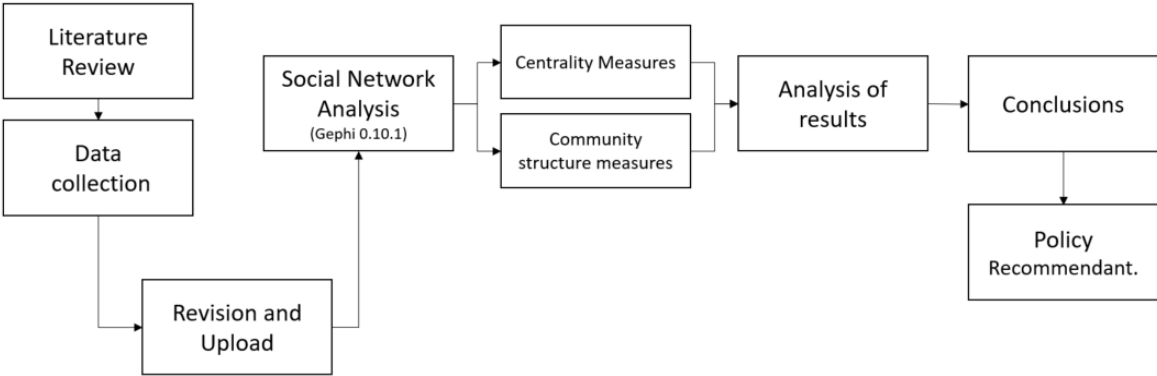
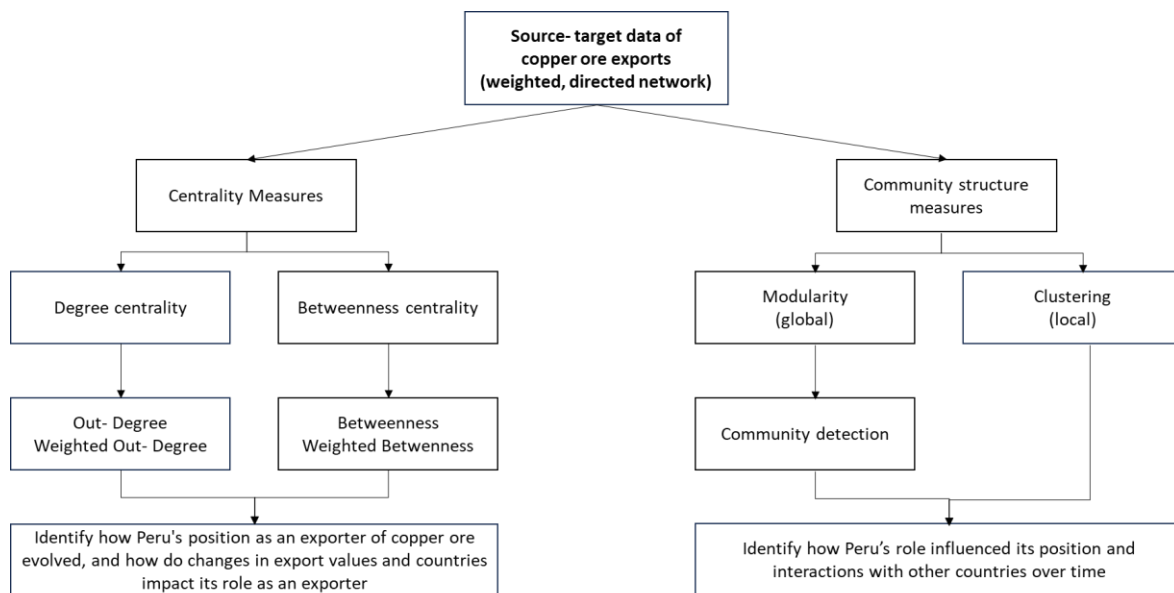


Figure 4 Methodology Framework

The Centrality Measures component dissects the network to determine the importance of nodes (countries or entities) within the network, a detail can be found in Figure 5 Social Network Analysis for the Methodology Framework. It encompasses Degree Centrality, which measures the number of direct connections a node has (Out-Degree and Weighted Out-Degree), and Betweenness Centrality, which considers the node's position as a conduit in the network's overall connectivity (Betweenness and Weighted Betweenness). These measures aim to quantify and trace the evolution of Peru's position as an exporter and how shifts in export values and interacting countries impact its role.

Complementing centrality measures are Community Structure Measures, which delve into the network's segmentation and the degree of its clustering. This involves Modularity to assess the network's division into modules and Clustering to evaluate the tight-knit grouping of nodes, concluding with Community Detection, which identifies the emergence of cohesive groups within the network.



*Figure 5 Social Network Analysis for the Methodology Framework*

Analysis of Results is the penultimate step, where the outcomes of the network analysis are scrutinized to draw meaningful inferences and understand the broader implications of the network's structure and dynamics.

Finally, the framework culminates with the Conclusions, synthesizing the insights gained from the analysis to formulate a coherent narrative of the findings. This leads to the Policy Recommendations, where strategic and actionable suggestions are presented to inform stakeholders and policymakers about optimizing Peru's role in the copper ore export market based on the evidence and patterns revealed through the social network analysis.

### **3.4. Data requirements and assumptions**

The research necessitates comprehensive international trade data, specifically focusing on copper ore. The data has been sourced from Trade Map, ensuring a robust and authoritative dataset that spans a ten-year period from 2013 to 2022. Trade Map is an online tool developed by the International Trade Centre (ITC), which is a joint agency of the World Trade Organization and the United Nations. It provides access to trade statistics and market access information for both international business development and research purposes. The data encapsulates an annual snapshot of up to 69 nations, effectively covering the full spectrum of the copper ore trading network. This

extensive dataset is critical as it provides the yearly granularity required to analyze trends and shifts in trade dynamics. The data must be complete, accurate, and reflect the actual export volumes in thousand tons, as these figures are fundamental to calculating the weighted measures in the social network analysis.

It has come to light that statistics from various nations exhibit inaccuracies or insufficiencies. Instances of such problems have been commonly identified in developing or tiny nations. The available dataset is of a restricted size and has undergone detection and cleansing processes. In order to expedite the temporal aspect of the Gephi process, the data pertaining to export volume has been converted from metric tons to thousands of metric tons.

In building the network model, several vital assumptions underpin the methodology. It is presumed that each nation within the dataset acts as an individual node within the network, and the economic relationships between these countries are depicted as directed and weighted links. These links represent the flow of copper ore exports, with the direction indicating the export journey from origin to destination, and the weight signifying the volume of these exports. The assumption that the trade connections are not reciprocal is crucial, as it reflects the reality of international trade where some nations are net exporters and others net importers. The directed nature of the network allows for a nuanced understanding of these trade relationships, differentiating between the influence of exporting and importing nations.

## Chapter 4 Results and Analysis

### 4.1. Network Overview

The general overview of the copper ore network between 2013 and 2022 provides a comprehensive picture of the trade dynamics over the span of a decade. This period has seen varying degrees of changes in the network's structure, as evidenced by the data collected on nodes, edges, and several network analysis metrics shown in Table 3 General overview of the copper ore network, 2013-2022.

*Table 3 General overview of the copper ore network, 2013-2022*

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Nodes</b>	67	64	64	64	65	65	62	67	69	63
<b>Edges</b>	230	222	229	238	230	232	226	228	241	217
<b>Average Degree</b>	3.433	3.469	3.578	3.719	3.538	3.569	3.645	3.403	3.493	3.444
<b>Average Weighted Degree</b>	265	289	452	519	552	561	592	509	525	596
<b>Network Diameter</b>	7	6	8	6	6	8	8	7	10	10
<b>Average Path Length</b>	2.63	2.558	2.472	1.994	1.966	3.099	2.516	2.2	2.646	2.926
<b>Graph Density</b>	0.052	0.055	0.057	0.059	0.055	0.056	0.06	0.052	0.051	0.056

In 2013, the network began with 67 nodes and 230 edges, indicating a relatively interconnected network. Over the years, the number of nodes fluctuated, peaking at 69 in 2021 and

then slightly dropping to 63 by 2022. The edges that represent the trade connections also saw fluctuations, with the highest count at 238 in 2016, reflecting an increase in trade activity or the entry of new trading partners.

The average degree of the network, which is a measure of the number of connections each node has, remained relatively stable over the years, signifying a consistent level of direct connections per country within the network. In contrast, the average weighted degree, which accounts for the volume of trade represented by the edges, showed an upward trend, peaking at 596 in 2022 from an initial 265 in 2013. This increase suggests a growing intensity in trade relationships, with more substantial amounts of copper ore being traded.

The network diameter, which measures the largest number of nodes that must be traversed to travel from one node to another, has generally remained low. This indicates a relatively small world effect, where any two countries are only a few steps away from each other within the network. It peaked at 10 in 2021 and 2022, suggesting a broadening of the network that might be due to the diversification of trade routes or new market entries.

The average path length shows a slight increase over the years, which aligns with the increase in network diameter. A longer path length could indicate that the network is becoming more expansive with trade routes requiring more steps to connect various nodes. The graph density remained low throughout the period, indicating that while the network is extensive, not every country is directly connected to every other, which is typical of large networks.

## **4.2. Centrality Analysis**

### *4.2.1. Degree Centrality Analysis*

#### 4.2.1.1. Out-Degree Centrality Analysis

The out-degree distribution of the copper ore trade network from 2013 to 2022 provides a comprehensive view of the network's evolution and its structural dynamics (Appendix 2). The majority of nodes within the network consistently exhibit a relatively low out-degree, indicating that most countries involved in the copper ore trade maintain a limited number of direct export connections. This pattern suggests that bilateral trade relations are prevalent, with a focus on a narrow set of trading partnerships rather than a diverse array of export destinations. Such a structure could

imply that many countries are dependent on a few critical markets for their copper ore exports, which may affect their economic stability and bargaining power in the global market.

As the Figure 6 Histogram of Out-Degree, 2013-2022 shows only a small subset of nodes, however, it displays a markedly higher out-degree, particularly noticeable in specific years. The histogram represents the distribution of out-degrees in the network from 2013 to 2022, showing a common characteristic of complex networks: a few nodes with high connectivity amidst a majority with lower connectivity. The log-scaled frequency axis highlights the steep decline in node count as out-degree increases, suggesting the existence of influential hubs. This distribution underscores the pivotal role a small number of nodes play in the network's overall structure.

These nodes are likely to represent countries that are significant exporters of copper ore, such as Peru. They act as central hubs within the network, exporting to a multitude of nations. The pivotal role these hub nodes play is indicative of their influence on the global copper ore trade, potentially impacting pricing, supply dynamics, and the resilience of the trade network to economic and political fluctuations.

The distribution of out-degrees across the network suggests a scale-free property, a common characteristic of many real-world networks. In a scale-free network, some nodes act as highly connected hubs, while most others have few connections. This architecture is typically robust against random disruptions but may be susceptible to targeted attacks on its most connected nodes. The implication for the copper ore trade network is that while it may be resilient to the fluctuation of smaller players, it could be vulnerable to changes affecting the major exporting countries.

Over the ten-year span, the network exhibits slight variations in the count of nodes with a particular out-degree, reflecting an evolving network structure. These changes could signify the emergence of new trading relationships, shifts in global demand, and the development of mining capacities in different regions. While the overarching scale-free nature of the network remains intact, these year-to-year fluctuations underscore the dynamic nature of the global copper ore trade, influenced by economic, geographic, and political factors that shape the trade landscape.

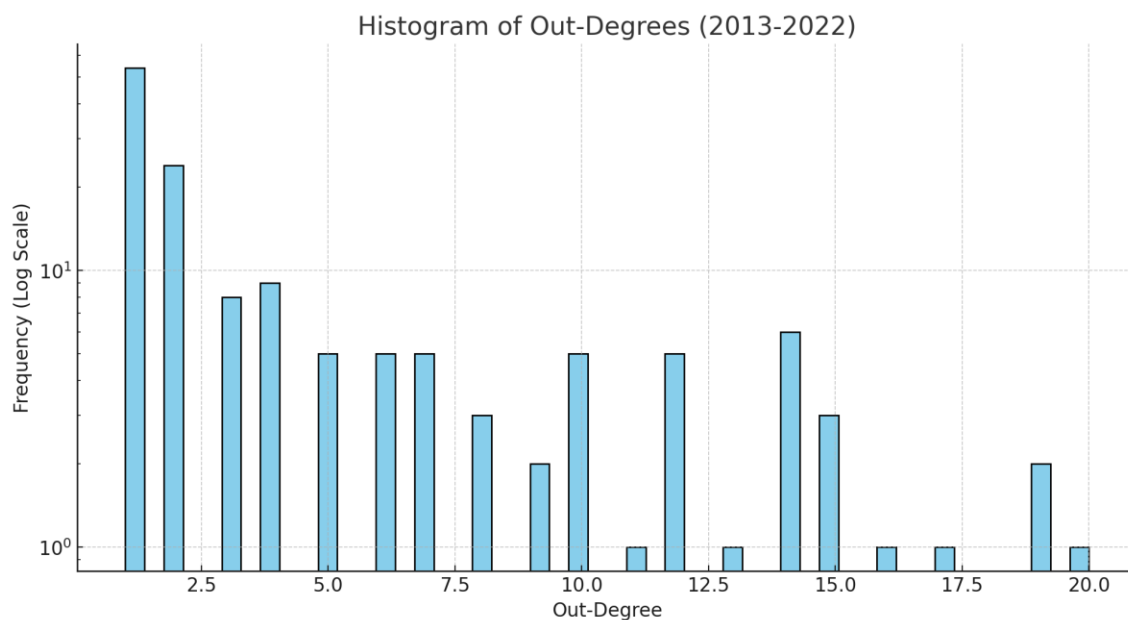


Figure 6 Histogram of Out-Degree, 2013-2022

#### Peru's out-degree case

The out-degree data for Peru from 2013 to 2022 is shown in the Table 4 Peru's centrality out-degree, 2013-2022, it showcases the number of connections that Peru has within the copper ore trade network. The out-degree is an indicator of how many direct trade relationships a country has through its exports. The normalized out-degree is a relative measure that typically divides the out-degree by the maximum possible out-degree in the network, providing a standardization that allows for comparison across different network sizes or across time.

In 2013, Peru started with an out-degree of 21 and a normalized out-degree of 0.318, reflecting its connectivity within the network at that time. By 2014 and 2015, both the out-degree and normalized out-degree saw an increase, suggesting that Peru was establishing more direct trade relationships, possibly expanding into new markets or strengthening its trade ties.

Furthermore, Peru is experiencing significant growth in demand due to its role as the second-largest producer. This demand is expected to meet the growing global population, projected to exceed 11 billion. However, the increased demand could lead to higher costs and reduced competitiveness



for industries heavily reliant on copper. To address this, Peru should develop a copper production strategy that aligns with its goals and implement tax policies to enhance the tax collecting system (Larios-Meño et al., 2021). However, in 2022, there was a marginal decrease of 0.3% in the export volume of significant metal mining commodities compared to the preceding year. This loss may be attributed to the imposition of COVID-19-related limitations in China, as well as the decrease in the international market prices of primary metals. The industrial sector had a notable increase in interannual exports of copper, with a growth rate of 8.0% (MINM, 2023).

Table 4 Peru’s centrality out- degree, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Out-Degree</b>	21	24	24	25	25	22	26	22	19	18
<b>Norm. Out-Degree</b>	0.318	0.381	0.381	0.397	0.391	0.344	0.426	0.333	0.279	0.290

However, a notable decrease occurs in 2020, with the out-degree dropping to 22 and the normalized out-degree falling to 0.333. This reduction could be attributed to the impact of the COVID-19 pandemic, which disrupted global supply chains and affected trade relations worldwide. The trend continues in 2021 and 2022, with further reductions in both out-degree and normalized values, indicating a contraction in Peru’s direct export connections. This contraction could signal a shift in global trade dynamics, changes in demand, or internal factors such as production constraints.

Overall, the fluctuations in Peru’s out-degree and normalized out-degree over the years highlight the changing landscape of global trade and Peru’s adaptive strategies within it. Despite recent contractions, Peru has demonstrated over the last decade an ability to expand its trade influence, although it must now navigate the challenges that have led to a reduction in its direct trade connections. These insights can inform future strategies for Peru to enhance its trade network resilience and capitalize on emerging opportunities in the global copper ore market.

4.2.1.2. Weighted Out-Degree Centrality Analysis

The weighted out-degree distribution charts from 2013 to 2022 provide insightful revelations about the nature of the copper ore trade network (Appendix 3). Over the ten-year span, the data

suggest a consistently skewed distribution, with most nodes having a low weighted out-degree. This characteristic indicates that most countries engage in a relatively small volume of copper ore exports, with their trade connections being limited in terms of the export amount represented by the weighted edges in the network.

The histogram of the network's weighted out-degree distribution demonstrates a typical power-law decay, indicating that most nodes have a low weighted out-degree, while a small number exhibit high out-degree values (Figure 7 Histogram of weighted Out-Degree, 2013-2022.). This pattern suggests the presence of a few influential hubs within a largely sparse network. Such hubs are critical to the network's structure and function, as they likely play a central role in connectivity and information flow. The observed distribution underscores the network's scale-free nature and highlights the importance of these hubs for maintaining network robustness and efficiency.

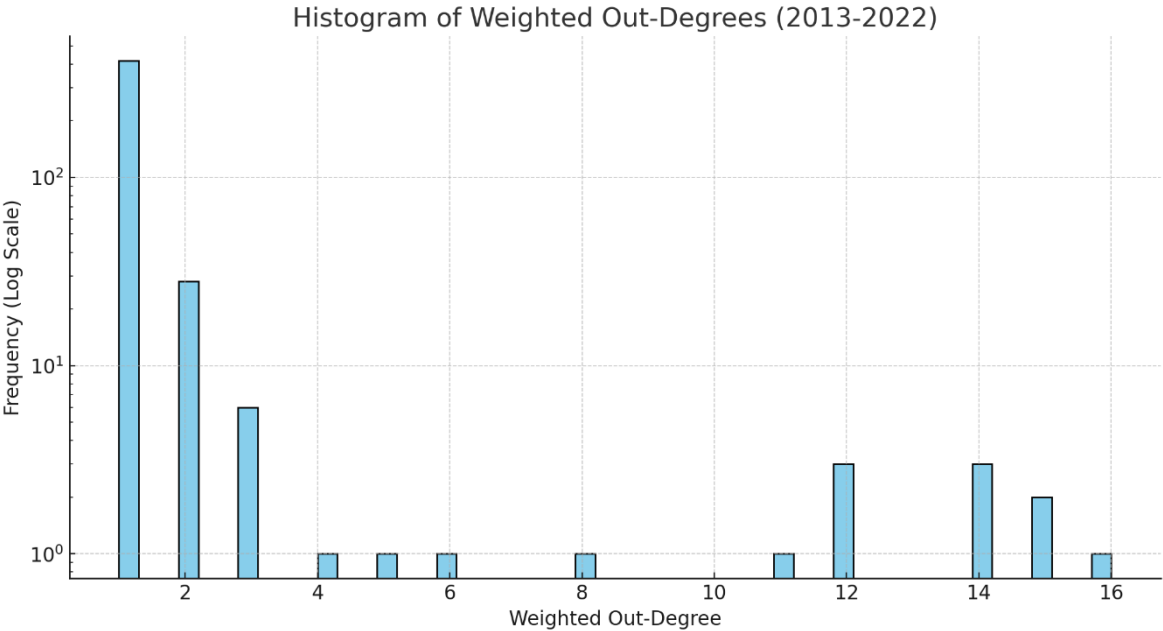


Figure 7 Histogram of weighted Out-Degree, 2013-2022.

A few nodes exhibit significantly higher weighted out-degrees, indicative of a small group of countries acting as major exporters in the copper ore trade network. These nodes are likely to be

influential within the network, potentially exerting control over pricing and market dynamics due to their substantial export volumes. Such a pattern is representative of a scale-free network where a few nodes (hubs) maintain a high number of weighted connections, dramatically exceeding the average, which aligns with the typical structure of many real-world networks including trade and social networks.

Over the years, the maximum weighted out-degree values appear to have increased, as seen in the charts for later years, suggesting that the top exporters are intensifying their trade connections. This could reflect a consolidation of market power among these key players or an increase in the global demand for copper ore, to which these countries are responding with heightened export activities.

The presence of such hubs within the network also speaks to the vulnerability of the network to targeted disruptions in these critical nodes. Should any of the major exporters face economic, political, or environmental challenges that affect their export capabilities, the entire network could experience significant impacts, reinforcing the importance of understanding and monitoring the activities of these critical players within the copper ore global market.

In conclusion, the analysis of the weighted out-degree distribution across the ten-year timeframe underscores the presence of a heterogeneously connected network with a few highly influential exporters. These exporters' roles in the global copper ore market are crucial and warrant further investigation to understand their impact on global supply chains and trade dynamics.

#### Peru's weighted out-degree case

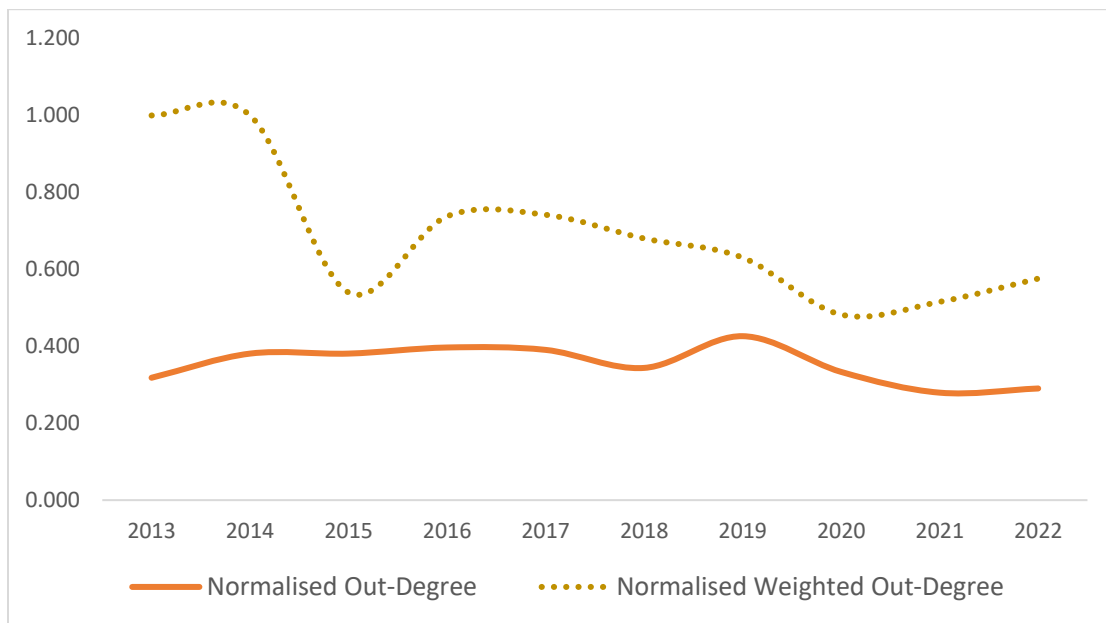
The results pertaining to Peru's weighted out-degree in the copper ore trade network from 2013 to 2022 offer a revealing glimpse into the country's evolving role as a global exporter. (Table 5 Peru's centrality weighted out- degree, 2013-2022) Initially, in 2013 and 2014, the normalized weighted out-degree for Peru stood at 1.000, indicating that during these years, Peru maintained a stable and possibly leading position in terms of export volumes within the network.

Table 5 Peru's centrality weighted out- degree, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Weighted Out-Degree</b>	3813	3896	5057	7617	8025	8256	8261	6151	6631	6651
<b>Norm. Weighted Out-Degree</b>	1.000	1.000	0.540	0.738	0.742	0.680	0.630	0.482	0.516	0.576

However, in 2015, there is a noticeable shift with the normalized weighted out-degree dropping to 0.540, and then gradually increasing in subsequent years, reaching 0.576 by 2022. This dip and subsequent recovery could suggest a temporary decrease in Peru's export volumes relative to the maximum out-degree observed in the network during that period.

From 2016 onwards, despite the fluctuations, there is an overall upward trend in the actual weighted out-degree values, peaking in 2018 with 8,256. This suggests that Peru was able to not only recover from the downturn observed in 2015 but also expand its export activities significantly. The year 2020 shows a decline to 6,151, which could be attributed to the global disruptions caused by the COVID-19 pandemic, impacting trade flows and economic activities. Nevertheless, the subsequent rise in 2021 and 2022 indicates a resilience in Peru's export capacity, showcasing an ability to adapt and recover from global trade disruptions.



*Figure 8 Peru's Degree Centrality, 2013-2022*

When juxtaposed with the network results, which exhibit a skewed distribution with a few nodes having high out-degrees, it becomes evident that Peru is among these influential nodes. Despite the observed variances over the decade, Peru's consistent presence as a node with a higher weighted out-degree underlines its strategic importance in the network. The country's copper exports are not only significant in volume but also critical for the connectivity and robustness of the global copper ore trade network.

In sum, the analysis of Peru's weighted out-degree within the copper ore trade network highlights the country's significant and fluctuating impact on the global stage. Understanding the nuances of these changes can provide valuable insights for policymakers and industry stakeholders in shaping strategies to enhance Peru's trade resilience, optimize its export potential, and navigate the complexities of the global market.

## 4.2.2. *Betweenness Centrality Analysis*

### 4.2.2.1. Betweenness Degree Centrality Analysis

The betweenness centrality distribution across the copper ore trade network from 2013 to 2022 provides a vital perspective on the roles various countries play within this network (Appendix 4). Betweenness centrality is indicative of a node's role as an intermediary in the shortest trade paths between other nodes. Nodes with high betweenness centrality are critical, as they often control the flow of goods and can influence trade dynamics due to their strategic positioning.

Throughout the decade, most nodes demonstrate low betweenness centrality scores, suggesting that most countries in the network directly trade with each other rather than relying on intermediaries. This characteristic could imply a network where bilateral trade agreements are predominant, and there is less reliance on third-party countries to facilitate trade. The decentralized nature of these connections might allow for more robust trade relationships that are less susceptible to single points of failure.

However, the presence of a few nodes with significantly higher betweenness centrality scores points to the existence of key intermediary nations within the network. These countries, by virtue of their position, have the potential to exert considerable influence over trade routes and to act as gatekeepers within the global copper ore trade. Their strategic importance within the network is underscored by their ability to affect trade flow, which can have broad implications for the global market, especially in times of geopolitical tension or supply chain disruptions.

The stability of the betweenness centrality distribution over the years indicates that the structural roles played by countries within the network remain relatively consistent. Countries that achieve a central intermediary role seem to maintain this status over time, which could be due to established trade relations or long-term strategic trade agreements. This continuity suggests that shifts in network dynamics are gradual rather than abrupt, providing a measure of predictability in the network's evolution.

Peru's betweenness case

In 2013 and 2014, Peru's betweenness centrality stood at 193, with normalized values at 0.045 and 0.049, respectively (Table 6 Peru's betweenness degree, 2013-2022). These figures suggest that while Peru had some influence within the network, it was not among the most central nodes. However, in 2015, there was a significant increase, with the betweenness centrality more than doubling to 343 and the normalized figure rising to 0.088, indicating a year of peak influence for Peru within the network.

This heightened intermediary role did not sustain, as seen by the drop in betweenness centrality to 131 in 2016, with a further decrease in 2017 to 114, reflecting a potential shift in trade patterns or a reduction in Peru's role as a trade route. The normalized values for these years, 0.034 and 0.028, confirm this downward trend. A surprising surge in centrality occurred in 2018, with betweenness centrality reaching the highest point of the decade at 436, and a normalized value of 0.108. This suggests a temporary strategic position for Peru within the trade network, possibly as a pivotal transit point for copper ore trade routes.

Subsequent years saw a decline, particularly sharp in 2020 and 2021, where the betweenness centrality fell to 74 and 42, respectively, with corresponding normalized values of 0.017 and 0.009. These years likely reflect the global disruptions caused by the COVID-19 pandemic, which could have severely impacted Peru's trade links. By 2022, there was a partial recovery to a betweenness centrality of 123 and a normalized value of 0.033, suggesting a gradual return to a more central role in the network, although not to the heights of 2015 or 2018.

*Table 6 Peru's betweenness degree, 2013-2022*

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Betweenness</b>	193	193	343	131	114	436	188	74	42	123
<b>Norm.</b>										
<b>Betweenness</b>	0.045	0.049	0.088	0.034	0.028	0.108	0.051	0.017	0.009	0.033

Throughout the decade, the variability in Peru's betweenness centrality underscores the changing dynamics of the global copper ore trade and the country's fluctuating influence within it. For stakeholders and policymakers, these metrics highlight the importance of understanding network positions and the potential impacts of global events on trade centrality.

#### 4.2.2.2. Weighted Betweenness Centrality Analysis

In assessing the international copper ore trade network from 2013 to 2022, weighted betweenness centrality measures reveal pivotal nations that act as critical intermediaries in the trade routes. Peru consistently emerges as a central hub within this network, with exceptionally high centrality in the years 2015 and 2018, emphasizing its critical role in the network's connectivity.

Spain's centrality escalates notably after 2015, peaking in 2022, indicating an increasing influence in bridging various parts of the network. The inclusion of Indonesia in this analysis underscores the dynamic and evolving nature of the copper ore trade network. The observed shifts in betweenness centrality for Indonesia, as well as the other key countries, highlight changes in trade relations and the strategic importance of these countries in the flow of copper ore. This variability in network roles is indicative of the complex interplay of economic, political, and logistical factors that drive international trade. Brazil shows a variable presence, with a resurgence in centrality in 2022, which may reflect a recent strategic enhancement in its trade linkages. Indonesia presents an interesting case; after a moderate presence in the early years, it experiences a lapse in centrality from 2016 to 2018, where it does not appear as an intermediary in the network. However, a resurgence from 2019 onwards and a significant increase by 2022 suggest a recovery and enhancement in its network role, marking it as a country of growing importance in the latter part of the decade.

#### Peru's weighted betweenness case

Peru's position in the international copper ore trade network is characterized by significant fluctuations in its centrality over the past decade. The raw weighted betweenness centrality scores highlight Peru's influential role, particularly in 2014, 2015, and 2018, where it reached peaks, suggesting that during these years, Peru was a primary conduit in the network, potentially controlling substantial flows of trade and connecting various segments of the market. For further detail look Table 7 Peru's weighted betweenness degree, 2013-2022.



In contrast, the years 2016, 2017, and especially from 2019 to 2021, indicate a reduced centrality, implying less influence or a shift in trade routes that bypassed Peru. The significant dip in 2021 could be attributed to various external factors, such as global market changes, as a consequence of COVID-19.

The normalized weighted betweenness centrality, which accounts for the network size and connectivity, follows a similar trend, with the highest normalized centrality observed in 2015. This peak reflects Peru's strategic importance in the network when compared to other nations. The normalization process helps to account for changes in the overall network structure and size, providing a more unambiguous indication of Peru's role relative to the total network activity.

The recent increase in both weighted and normalized betweenness centrality in 2022 is particularly noteworthy. It suggests a resurgence in Peru's centrality, indicating that it has regained or even strengthened its role as a significant intermediary in the trading network.

Overall, Peru's centrality metrics underscore its vital role in the structure of the international copper ore trade network, with its ability to influence trade flows varying significantly throughout the examined period.

*Table 7 Peru's weighted betweenness degree, 2013-2022*

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Weighted betweenness</b>	180	348	464	165	143	474	226	88	75	281
<b>Norm. Weighted betweenness</b>	0.042	0.089	0.119	0.042	0.035	0.121	0.062	0.021	0.016	0.074

*4.2.3. Centrality Integration and Network Influence*

In order to find the most powerful nodes in the network, a centrality integration analysis has been done by combining degree centrality and betweenness centrality. The four measures applied before has been done graph with the help of a geolayout in Gephi. In the following graphs from Figure

9 to Figure 18, the color of the nodes and edges represents the weighted-out degree centrality. To represent the weighted-out degree, we can look on the color of the label of nodes and thickness of edges. In case of a more intense color and a thicker edge, it means a higher weighted out-degree result. To check the weighted betweenness, the size of the node is the indicator.

Yearly analysis

### 2013: Establishing a Baseline

The network's inception year shows initial trade patterns. Countries like Chile and Peru demonstrate high weighted out-degree, indicative of their dominant export positions. Betweenness centrality suggests that certain nations are already positioning themselves as trade hubs, with Peru being notably influential (Figure 9).

Peru begins with solid out-degree centrality, indicating active trade relations with numerous countries. Its weighted out-degree is the maximum among the observed years, signifying a high volume of trade, corroborated by a normalized score of 1.00, indicating its leading role. Betweenness centrality is moderate, but it is notable that Peru is emerging as a significant intermediary in the network.

Year: 2013 N.W.O.D: 1.000 N.W.B.C:0.042

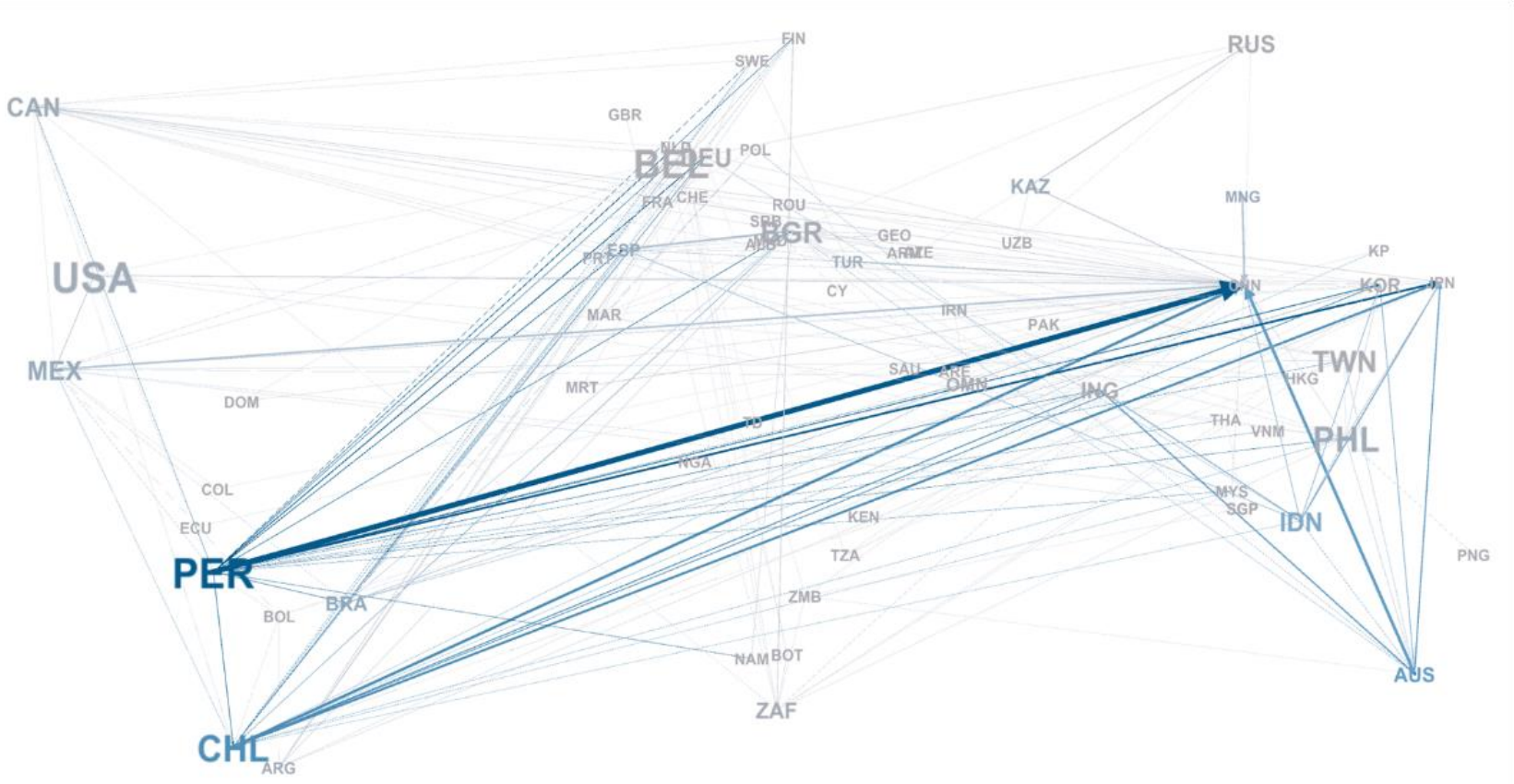


Figure 9 Copper ore trade network by weighted out-degree and weighted betweenness, 2013

Year: 2014 N.W.O.D: 1.000 N.W.B.C:0.089

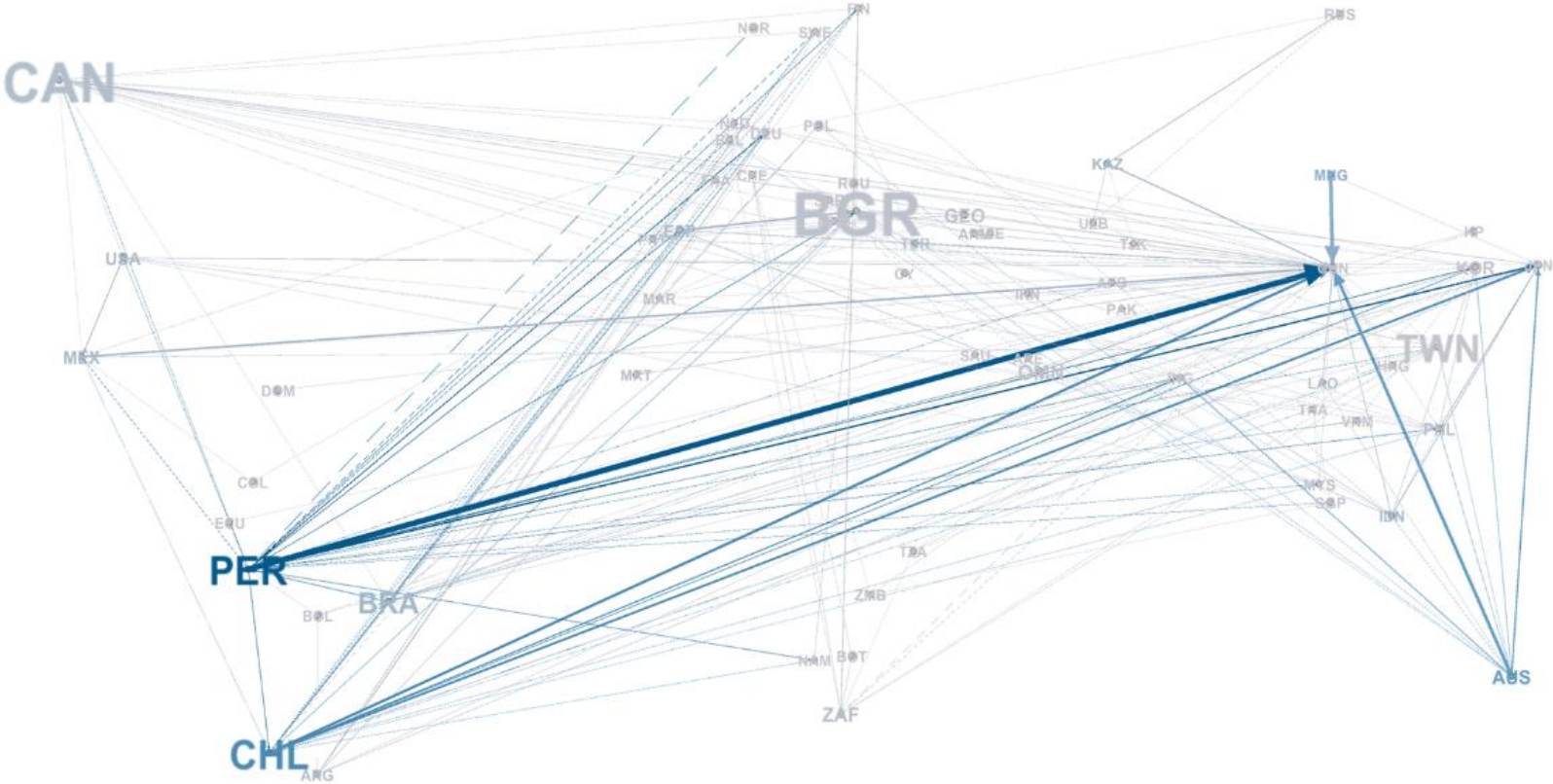


Figure 10 Copper ore trade network by weighted out-degree and weighted betweenness, 2014

#### 2014: Expansion and Connectivity

A noticeable increase in the weighted out-degree of several countries reflects an expansion in trade agreements and partnerships. Weighted betweenness centrality reveals that certain countries are beginning to control larger volumes of trade, with Peru maintaining a significant role as shown in Figure 10.

Peru's out-degree centrality remains stable, reflecting sustained trade relationships. Weighted out-degree drops slightly yet maintains a high normalized score, sustaining its leading position. Betweenness centrality remains unchanged, signifying a steady influence over trade routes.

#### 2015: Shifting Dynamics

As be shown in Figure 11, some countries experience a dip in out-degree centrality, possibly due to market fluctuations or shifts in copper ore demand. The network's weighted out-degree measure indicates increased competition, with new players emerging in the market.

Peru's out-degree centrality stays consistent, but there is a notable peak in betweenness centrality, suggesting that Peru has become even more central to the network's trade flow. This year marks its highest normalized betweenness, reinforcing its role as a critical intermediary. On the other hand, Chile decreased notably in betweenness but have a more intense color because of the increase in weighted out-degree.

Year: 2015 N.W.O.D.:0.540 N.W.B.C.:0.119

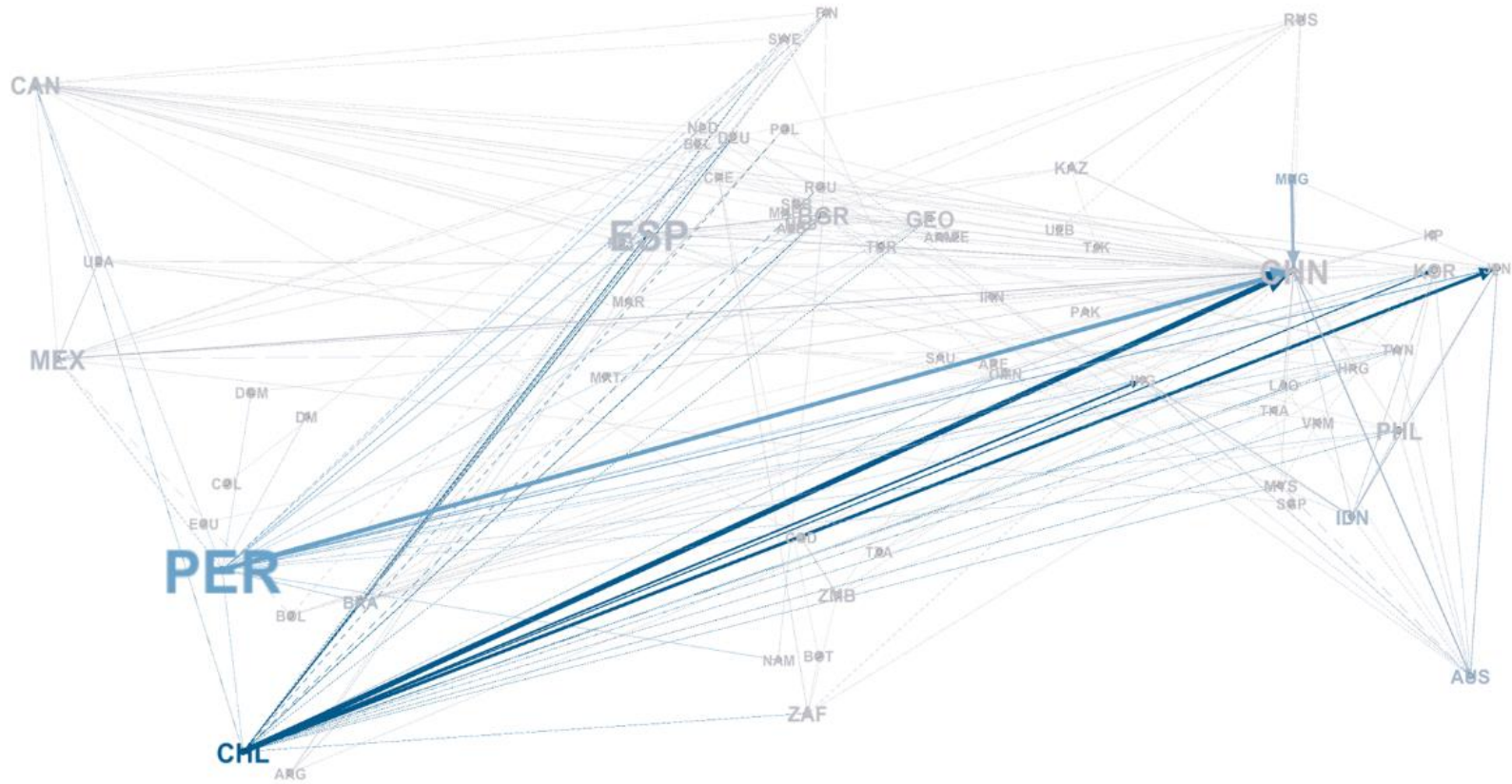


Figure 11 Copper ore trade network by weighted out-degree and weighted betweenness, 2015

Year: 2016 N.W.O.D:0.738 N.W.B.C:0.042

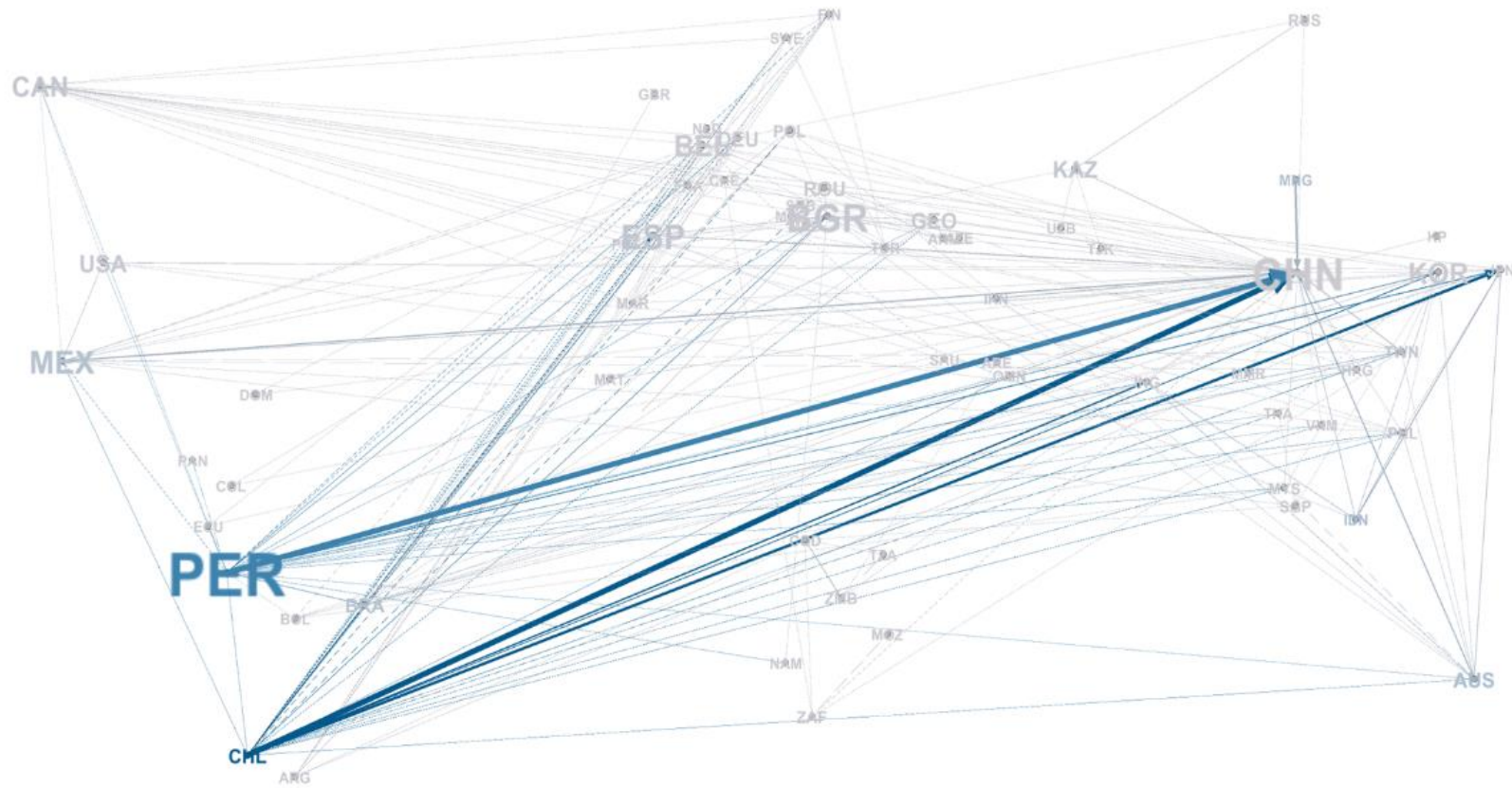


Figure 12 Copper ore trade network by weighted out-degree and weighted betweenness, 2016

### 2016: Consolidation and Strategic Positioning

The network sees a consolidation phase with central countries fortifying their positions. Betweenness centrality scores highlight the pivotal role of countries as intermediaries in the network (Figure 12).

While weighted out-degree centrality increases, there is a sharp drop in betweenness centrality, signaling a potential shift in Peru's intermediary role within the network. Weighted out-degree rises, reflecting an increase in trade volume, although the normalized measure starts to decline, possibly indicating other countries are gaining in trade volume relative to Peru.

### 2017: Realignment and Response to Market Forces

Looking to Figure 13, changes in weighted betweenness centrality suggest a realignment of the network's intermediary nodes. Market forces and economic policies begin to significantly impact the network's trade flow, as evidenced by the centrality measures.

Betweenness centrality decrease, hinting at a consolidation of Peru's trade connections and a reduction in its intermediation. However, weighted out-degree remains high, suggesting that while the number of trade partners may have shrunk, the volume of trade remains substantial.

### 2018: Intensification of Trade Relationships

An intensification of trade relationships is observed, with increased weighted out-degree centrality among top exporters. The network's modularity may indicate the formation of more substantial trade blocs or alliances (Figure 14).

A further decline in out-degree centrality and a significant dip in betweenness centrality highlight a continued diminishing role for Peru in the network. Despite this, weighted out-degree centrality remains high, indicating that trade volume is still significant, albeit with fewer partners. Chile consolidated as the major exporter in the network.



Year: 2017 N.W.O.D: 0.742 N.W.B.C: 0.035

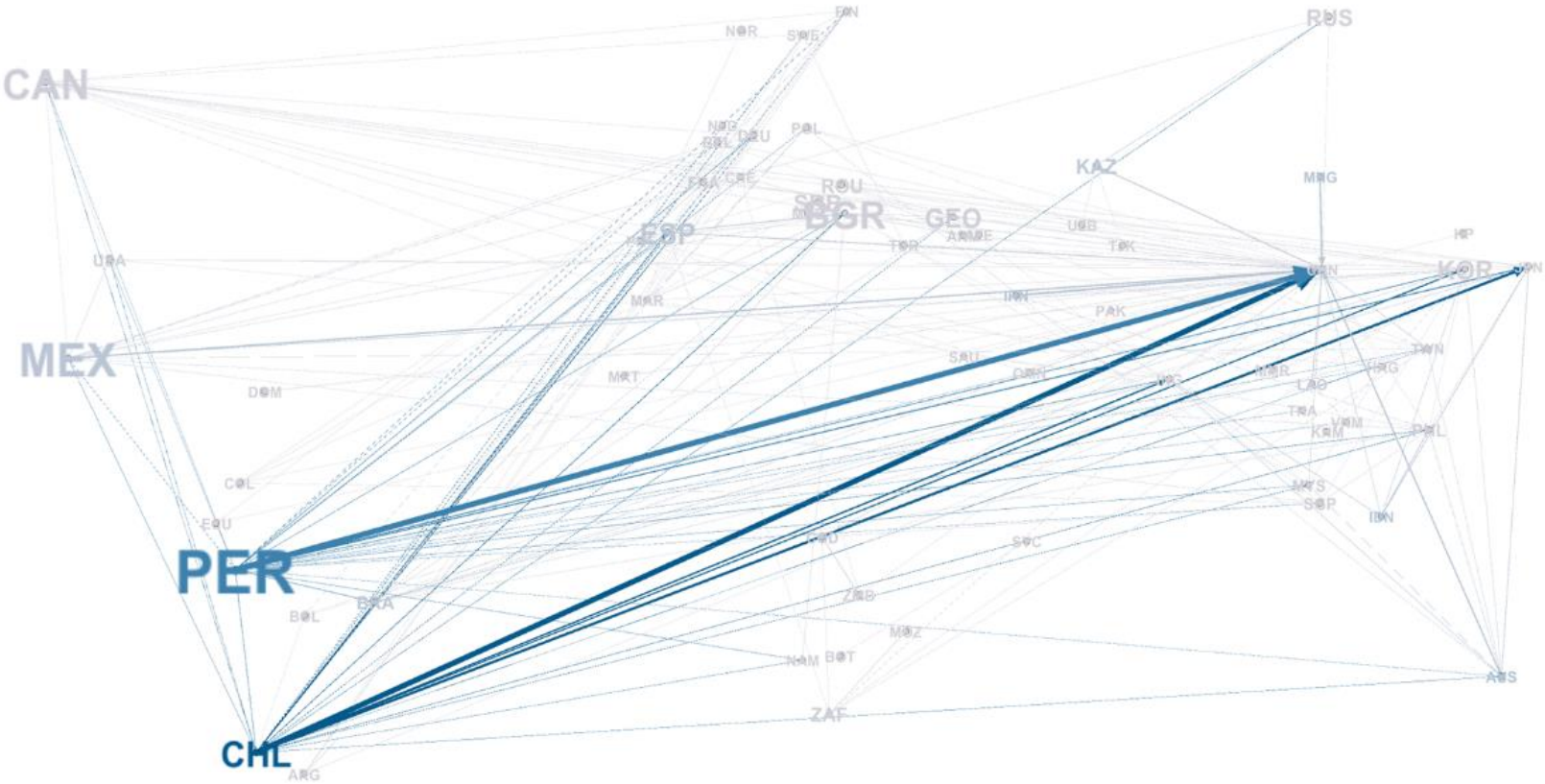


Figure 13 Copper ore trade network by weighted out-degree and weighted betweenness, 2017

Year: 2018 N.W.O.D.:0.680 N.W.B.C.:0.121

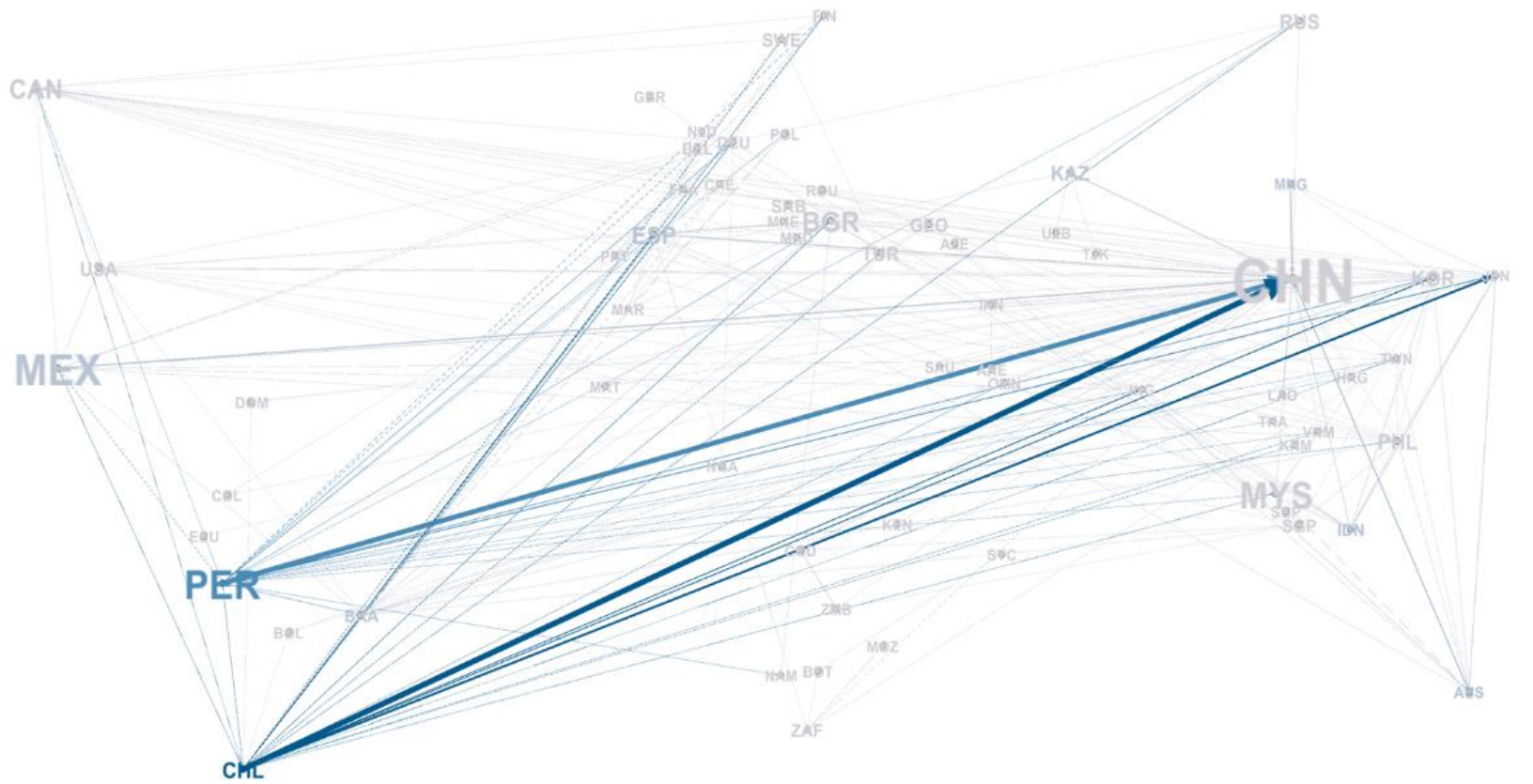


Figure 14 Copper ore trade network by weighted out-degree and weighted betweenness, 2018

### 2019: Pre-Pandemic Trade Patterns

The final year before the pandemic shows stable out-degree centrality, suggesting robust trade relationships. Betweenness centrality indicates that some countries are solidifying their roles as crucial connectors within the network (Figure 15).

Weighted betweenness centrality experiences a recovery, suggesting an enhanced intermediary position for Peru. The normalized weighted out-degree indicates a competitive trade volume, despite a lower normalized score than earlier years. Meanwhile, Indonesia started to be a key player in the network.

### 2020: Pandemic Disruption

The onset of the COVID-19 pandemic disrupts traditional trade patterns, impacting centrality scores across the network. A dramatic shift in betweenness centrality reflects the disruption of trade routes and the reconfiguration of the network.

The global disruption caused by the COVID-19 pandemic is reflected in a significant reduction in both measures for Peru. The drop in weighted measures indicates a substantial impact on Peru's trade volume and its intermediary role within the network.

### 2021: Adaptation and Recovery

As countries adapt to the pandemic, new trade patterns emerge, with some nations recovering or even improving their centrality measures. The network's resilience is tested, with the weighted betweenness centrality measure highlighting the countries that successfully navigate the changing landscape.

There is a continued struggle for Peru to regain its previous position, with all centrality measures remaining low compared to earlier years. However, the slight increase in normalized weighted betweenness hints at a small recovery in its role as a trade intermediary. Most of the countries lost power with few exceptions, like Indonesia.

Year: 2019 N.W.O.D: 0.630 N.W.B.C: 0.062

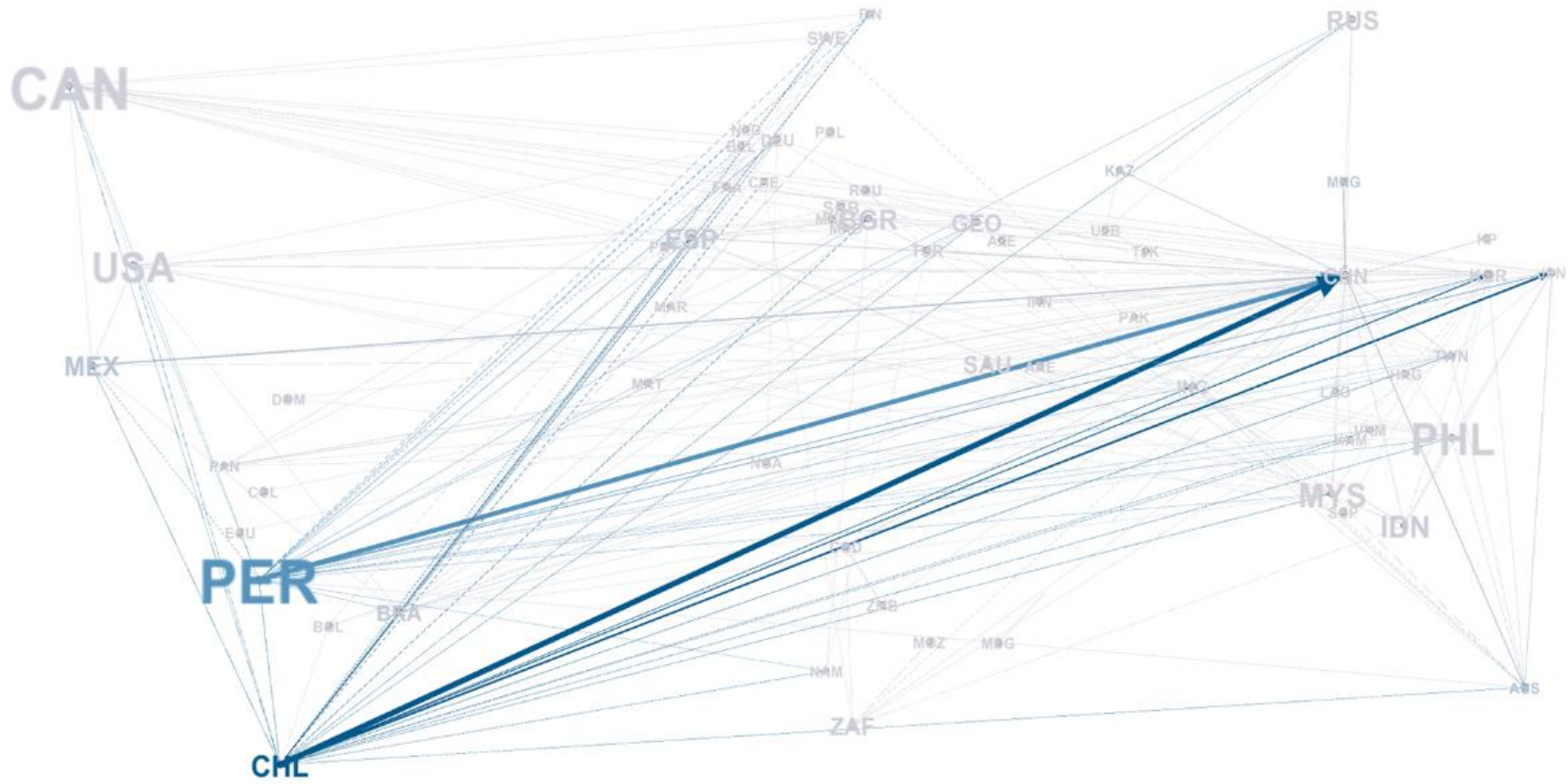


Figure 15 Copper ore trade network by weighted out-degree and weighted betweenness, 2019

Year: 2020 N.W.O.D: 0.482 N.W.B.C: 0.021

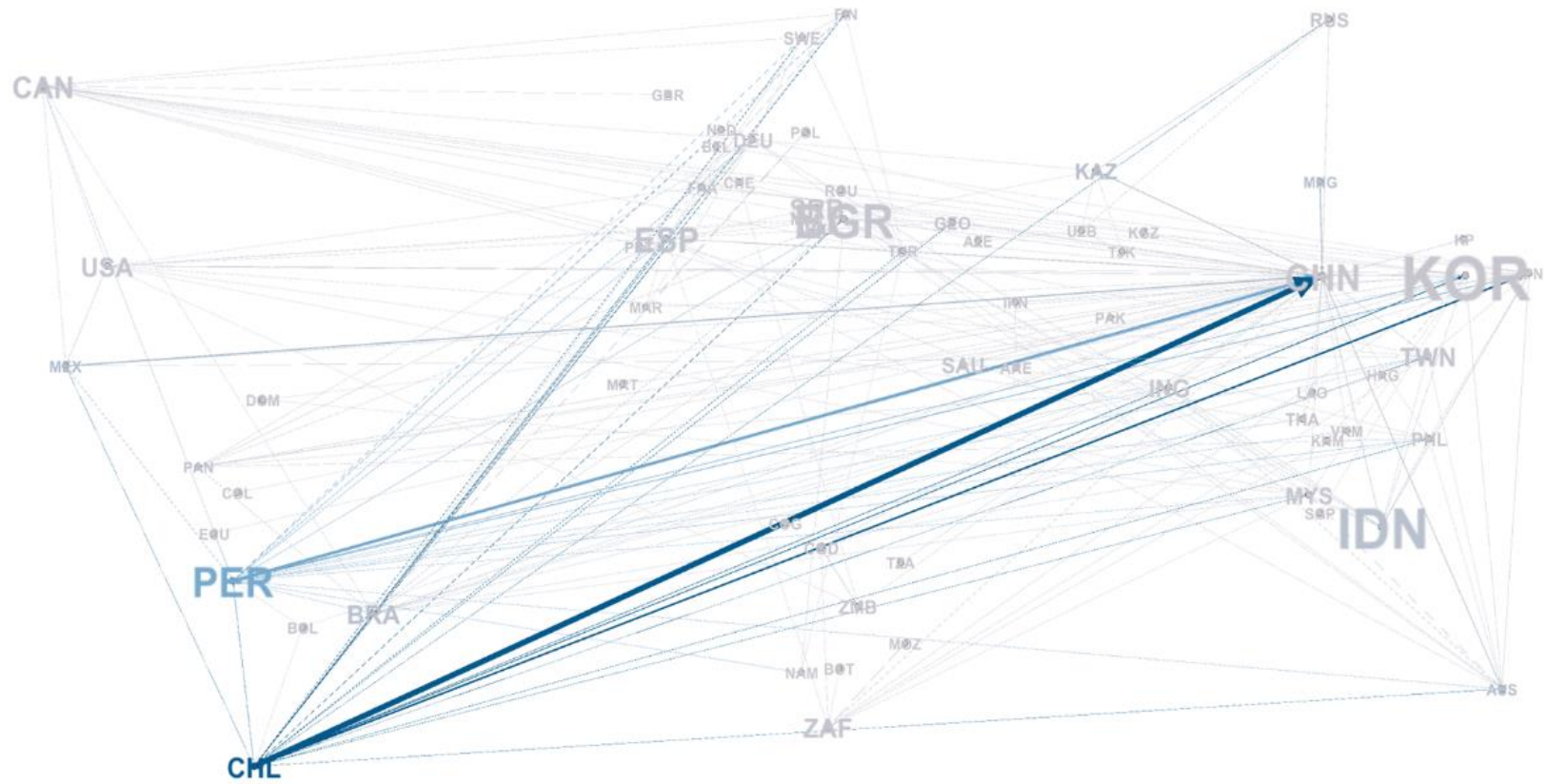


Figure 16 Copper ore trade network by weighted out-degree and weighted betweenness, 2020

Year: 2021 N.W.O.D.:0.516 N.W.B.C.:0.016

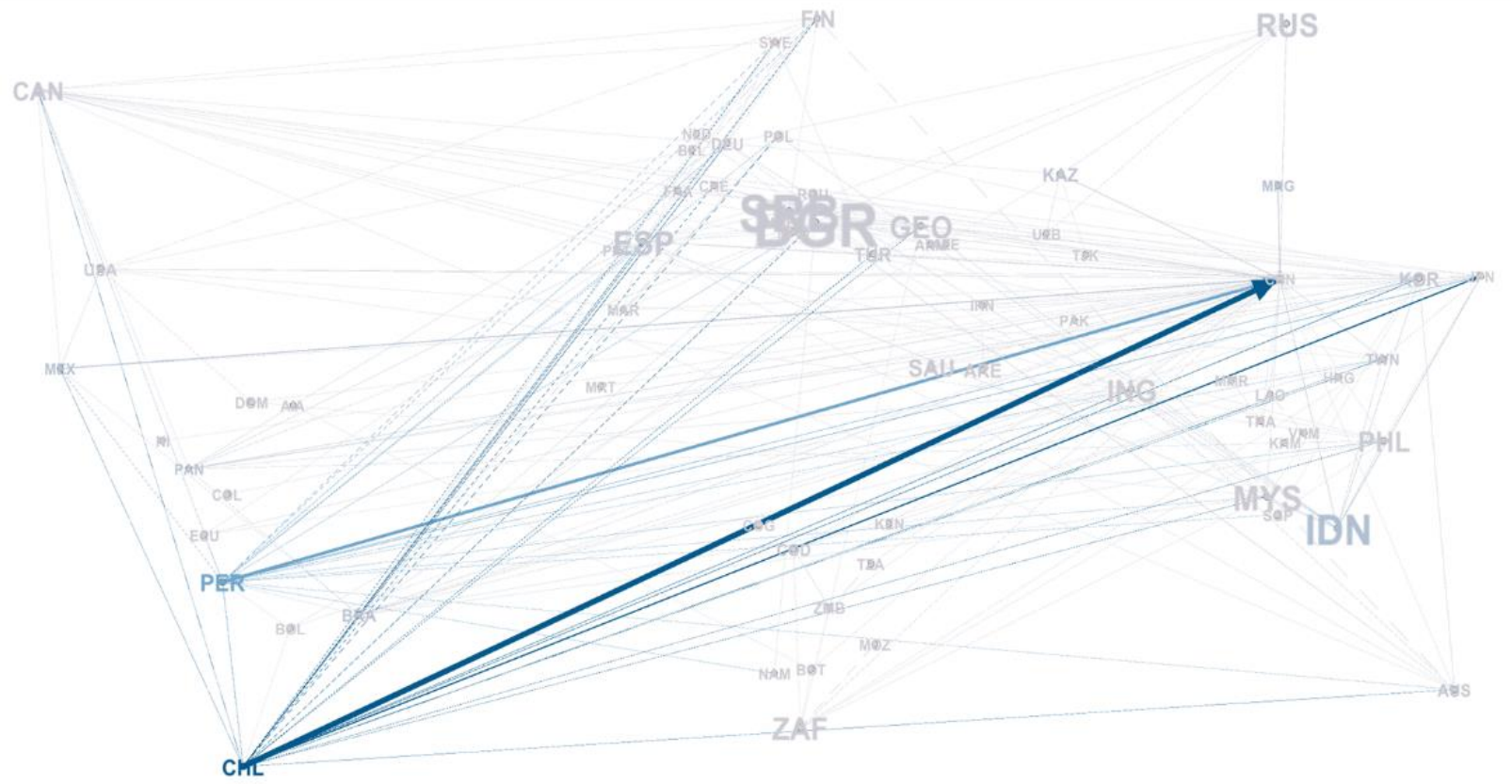


Figure 17 Copper ore trade network by weighted out-degree and weighted betweenness, 2021

## 2022: Establishing the New Normal

The network begins to establish a new normal, with some countries regaining or surpassing their pre-pandemic centrality levels. The year's centrality measures will be critical in understanding the long-term impacts of the pandemic on international trade.

A slight uptick in betweenness centrality and its normalized measure in 2022 suggests the beginnings of a resurgence for Peru's intermediary role. While still below earlier years, the increase in normalized weighted betweenness indicates an improvement in Peru's control over trade flows. Brazil and Indonesia gain power after COVID-19 impact.

### Timeline analysis

Throughout the examined timeline, the visual prominence of the edges connecting Peru-China and Chile-China is notable, characterized by their more intense coloration and greater thickness. This vivid representation signifies the robust trade relations between these countries, particularly pronounced in 2013 and 2014. However, a gradual fading of the edges from 2015 onwards reflects a decline in Peru's trade prominence, as evidenced by the decrease in normalized weighted out-degree from a full score of 1.00 in 2013 to 0.576 by 2022. This attenuation symbolizes Peru's progressive loss of influence in the copper ore market, while concurrently, Chile's ascension as a primary volume exporter becomes increasingly apparent.

In the span from 2015 to 2022, Peru consistently maintained the second rank in weighted out-degree, trailing Chile. Nevertheless, the disparity between the two nations is striking. For instance, in 2017, the gap was a marginal 0.258 points; by contrast, 2020 witnessed an expansion to 0.517 points, an alarming surge of 50%. Such divergences underscore the shifting dynamics within the network.

The analysis of weighted betweenness reveals a significant augmentation of Peru's centrality from 2015 to 2019, indicating its crucial role as a conduit in trade flows. Nevertheless, a diminution in influence is starkly observed in 2020, as illustrated by the reduced node size and a plummeting normalized weighted betweenness from 0.062 to 0.021. This decline is mirrored in the centrality rankings, with Peru descending from the pinnacle in 2015 and 2016 to a lower echelon by 2020.

Year: 2022 N.W.O.D: 0.576 N.W.B.C: 0.074

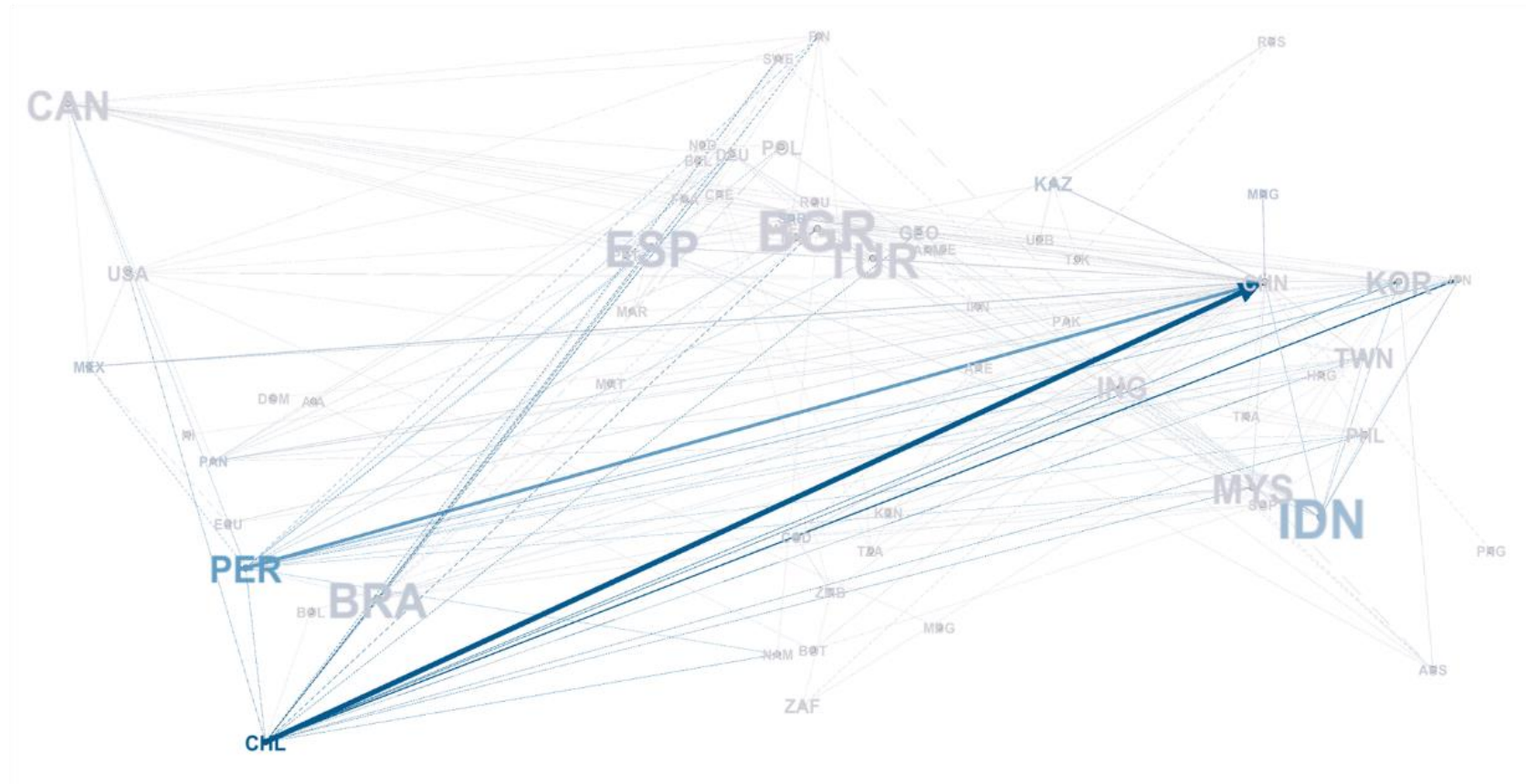


Figure 18 Copper ore trade network by weighted out-degree and weighted betweenness, 2022



However, 2022 marks a period of recuperation for Peru, as it advances to the fourth rank, suggesting a resilient rebound.

The waning of Peru's influence is mainly attributable to the COVID-19 pandemic's ramifications. In contrast, countries like Indonesia and Brazil have not only sustained but, in some instances, augmented their network centrality during the crisis. Indonesia's persistent growth in both weighted out-degree and betweenness, along with Brazil's steadfast export volumes, reflect a strategic fortitude amidst global upheaval. For Peru, a strategic recalibration is imperative, focusing on expediting post-pandemic recovery to restore and potentially enhance its standing within the global copper ore trade network.

#### Peru's ranking by measure in the timeline

To analyze the importance of Peru from another perspective the Figure 19 shows the heatmap which reveals Peru's prominence in the international copper ore trade network through four centrality measures: Out-Degree, Weighted Out-Degree, Betweenness, and Weighted Betweenness. The green color denotes a higher position in the ranking while a redness color a lower position in comparison with other years.

In the Out-Degree and Weighted Out-Degree categories, Peru consistently ranks first or second from 2013 to 2019, indicating its role as the most active trader in terms of number and weight of connections to other countries. A slight dip to the second rank in 2021, followed by a return to the top in 2022, suggests a temporary shift in trade dynamics.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Out-Degree</b>	1	1	1	1	1	1	1	1	2	1
<b>Weighted Out-Degree</b>	1	1	2	2	2	2	2	2	2	2
<b>Betweenness</b>	2	4	1	1	1	3	1	4	13	8
<b>Weighted betweenness</b>	7	3	1	1	2	5	3	11	11	4

Figure 19 Peru's ranking heatmap by measure, 2013-2022

Betweenness centrality shows Peru's importance as an intermediary in the trading network, peaking with the top rank in from 2015 to 2017, and 2019. The significant drop to the 13th rank in 2021 is an anomaly that merits further examination, as it implies a drastic reduction in Peru's role as a connector between different parts of the network. Furthermore, 2022, makes a recovery on the 8<sup>th</sup> position.

The Weighted Betweenness measure, which accounts for the volume of trade flow through Peru, shows more variability. While Peru holds the top position in several years, it experiences a lower ranking in 2020 and 2021, and a rise again in 2022. The rankings in this category suggest changes in the significance of the trade volume for which Peru acted as an intermediary.

This analysis underscores Peru's significant and, at times, fluctuating role in the copper ore trade network. The country's strong performance across most centrality measures highlights its strategic importance, especially in directing trade flows and connecting various market segments. The heatmap's color transitions from green to red, particularly in Betweenness and Weighted Betweenness, reflect the changing influence of Peru in the network over the past decade. With a decreased in 2020 and 2021, showing a significant recovery in 2022, not enough to equals pre-pandemic levels.

### **4.3. Community Structure Analysis**

#### *4.3.1. Modularity Analysis*

Modularity is a measure of the structure of networks that quantifies the degree to which the network may be subdivided into such clearly delineated groups or communities. A higher modularity score indicates a strong division of the network into communities with dense connections internally and sparser connections between communities.

From 2013 to 2022, the modularity of the network fluctuates, with an initial increase from 2013 (0.231) to 2014 (0.276), suggesting a strengthening of community structures. However, a notable decrease in modularity is observed from 2015 onwards, reaching a low in 2020 (0.063). This could indicate a more integrated network over time with less distinct community structures. The number of communities within the network also shows variation, starting with four in 2013 and peaking at five from 2014 to 2018 (Table 8 Modularity of the network and number of communities,

2013-2022). From 2019 onwards, there is a downward trend in the number of communities, ending with two in 2022. The decreasing number of communities, along with lower modularity, could suggest a consolidation in the network, where fewer but potentially more connected trade groups emerge.

Table 8 Modularity of the network and number of communities, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Modularity</b>	0.231	0.276	0.177	0.115	0.155	0.133	0.119	0.063	0.067	0.076
<b>Number of communities</b>	4	5	5	5	5	5	3	4	3	2

The graph 'Modularity and N° communities' (Figure 20) visually represents these trends, with modularity depicted by a dotted line and the number of communities by a solid line. The divergence of these two lines, especially from 2018 to 2022, is notable. While modularity experiences a slight increase in 2022 after a period of decline, the number of communities continues to decrease, which may reflect an ongoing process of network consolidation, where the remaining communities become less modular but possibly more interconnected.

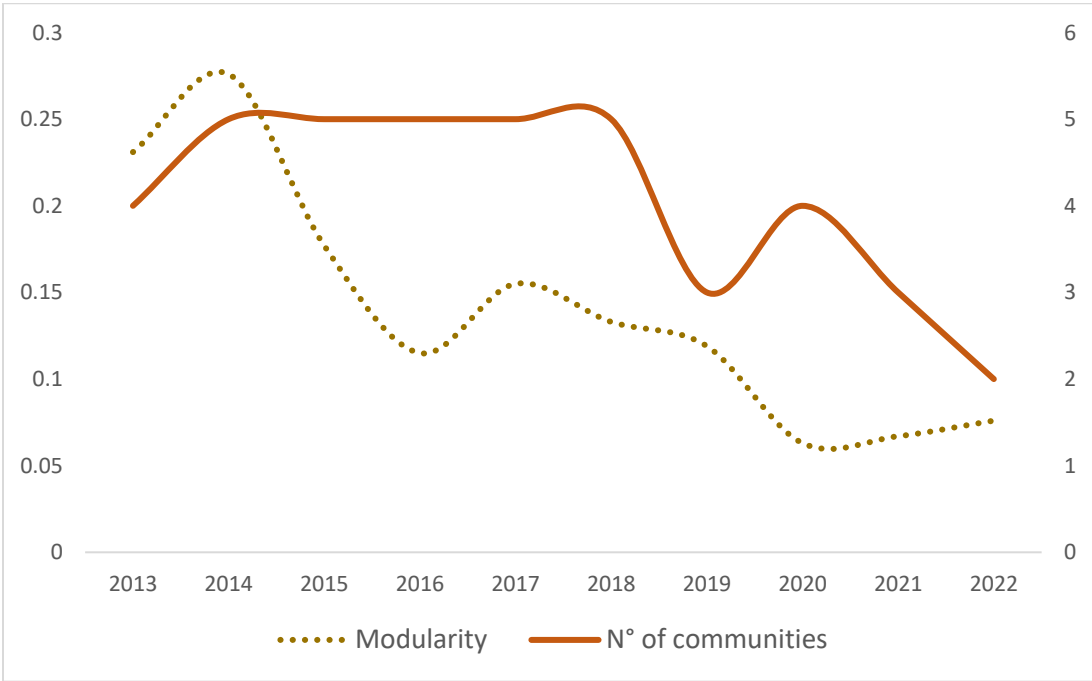


Figure 20 Modularity of the network and number of communities, 2013-2022

This trend could be influenced by several factors, including global market consolidation, changes in trade policies, or shifts in supply and demand dynamics. These changes in modularity and community structure have essential implications for the resilience and robustness of the network, as they may affect how the network responds to disruptions or changes in trade patterns.

### 4.3.2. Clustering Analysis

Clustering coefficient measures the degree to which nodes in a network tend to cluster together. A higher clustering coefficient indicates a greater propensity for nodes to form tight-knit groups, which can enhance resilience and facilitate information flow within those groups.

Table 9 Average network clustering of the network and Peru’s measure, 2013-2022

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
<b>Average Network clustering</b>	0.328	0.355	0.379	0.396	0.341	0.376	0.401	0.337	0.356	0.300
<b>Peru's clustering</b>	0.257	0.211	0.243	0.275	0.265	0.285	0.272	0.283	0.346	0.332

The average network clustering coefficient shows an overall fluctuating trend with a peak in 2019 (0.401), suggesting that the network had the highest tendency to form interconnected trading groups during that year (Table 9 Average network clustering of the network and Peru’s measure, 2013-2022). This could reflect a period of increased market integration or a strategic emphasis on strengthening trade relationships.

Peru's clustering coefficient, while generally lower than the network average, shows a similar fluctuating pattern. Notably, Peru's coefficient exhibits a significant increase in 2021 (0.346) and remains relatively high in 2022 (0.332), indicating that Peru's trade connections were particularly close-knit, with more robust direct trading links between its immediate trade partners during these years.

The graph 'Clustering of the network' (Figure 21) visually represents these trends with two lines: one for the network's average clustering (solid line) and another for Peru's clustering (dotted line). The convergence of these lines in later years suggests that Peru's trade network was becoming more similar to the network's overall clustering pattern, potentially indicating a strategic alignment of Peru's trade practices with the broader network trends. The observed differences between the network average and Peru's clustering across the years could be influenced by specific trade policies, regional trade agreements, or shifts in the global demand for copper ore. These factors might affect the degree of clustering by encouraging the formation of trade cliques or influencing the overall structure of the trade network.

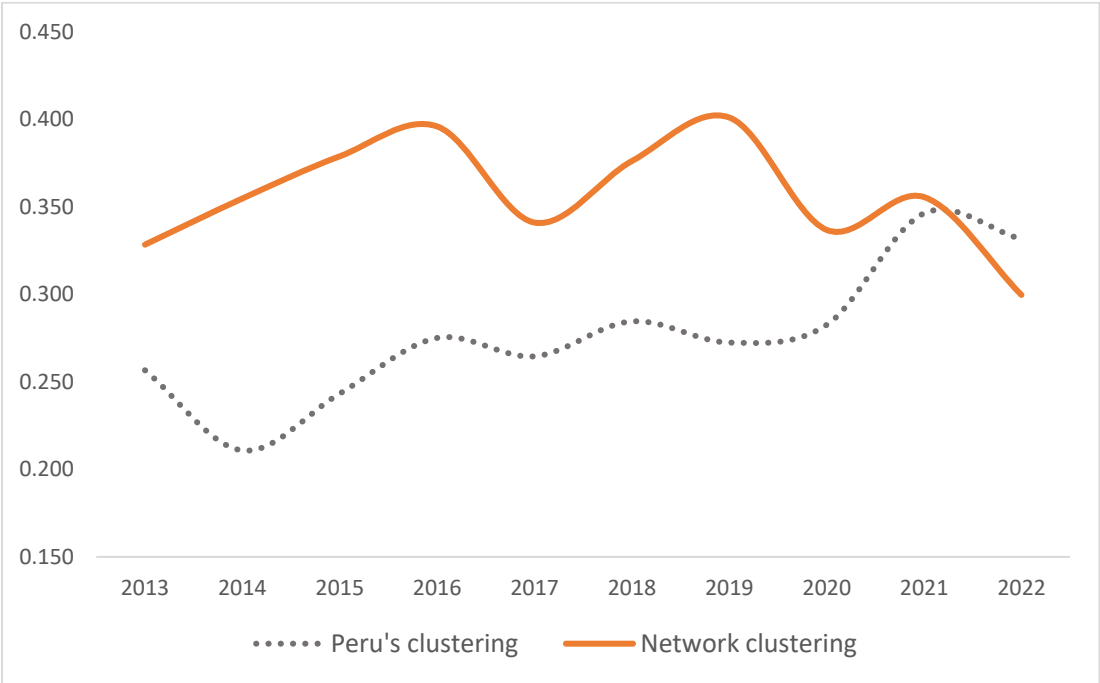


Figure 21 Clustering of the network

### 4.3.3. Community Analysis

Modularity had been run in Gephi. The name of communities is represented by a number and a color randomly by year. There is not a specific name for specific countries because the analysis had been done yearly. The purpose of running the partition is to identify the market concentration and the countries that are participating in the same community every year (Appendix 5).

Between 2013 and 2018, the network's modularity classes ranged from four to five, indicating a relatively stable community structure within the global copper ore trade. Modularity, a measure that reflects the strength of division of a network into modules or communities, suggests that during this period, the network was characterized by distinct trade groups. Each modularity class represents community of nations with dense internal trade connections and sparser connections between different communities, for further detail look Figure 22.

In 2013, the network began with four modularity classes, with Class 0 being the largest (43.28%), representing the central community within the trade network. This pattern persisted into 2014, with an increase in the proportion of Class 0, signifying potential consolidation within the central trading community or growth in trade volume and connections within this group.

As we move into 2015, the proportion of Class 0 decreases, while other classes become more prominent. This shift may indicate diversification within the network as trade patterns evolve, possibly due to changes in global demand, shifts in market strategies, or political and economic developments influencing trade policies.

In 2016 and 2017, the pattern of modularity shifts, reflecting further changes in the network's community structure. The fluctuating sizes of the modularity classes across these years highlight the dynamic nature of the international copper ore trade, with nations forging and dissolving trade connections in response to a myriad of factors. The largest community represents around 50%

Post-2018, we observe a significant consolidation within the network, as indicated by the decrease in the number of communities and the increasing dominance of a single modularity class. By 2020, Class 0 engulfs a vast majority of the network, which may be a result of several nations merging their trade relations into a more unified bloc, possibly as a strategic response to the challenges posed by the COVID-19 pandemic. This year, the largest community goes up to 68.66%-

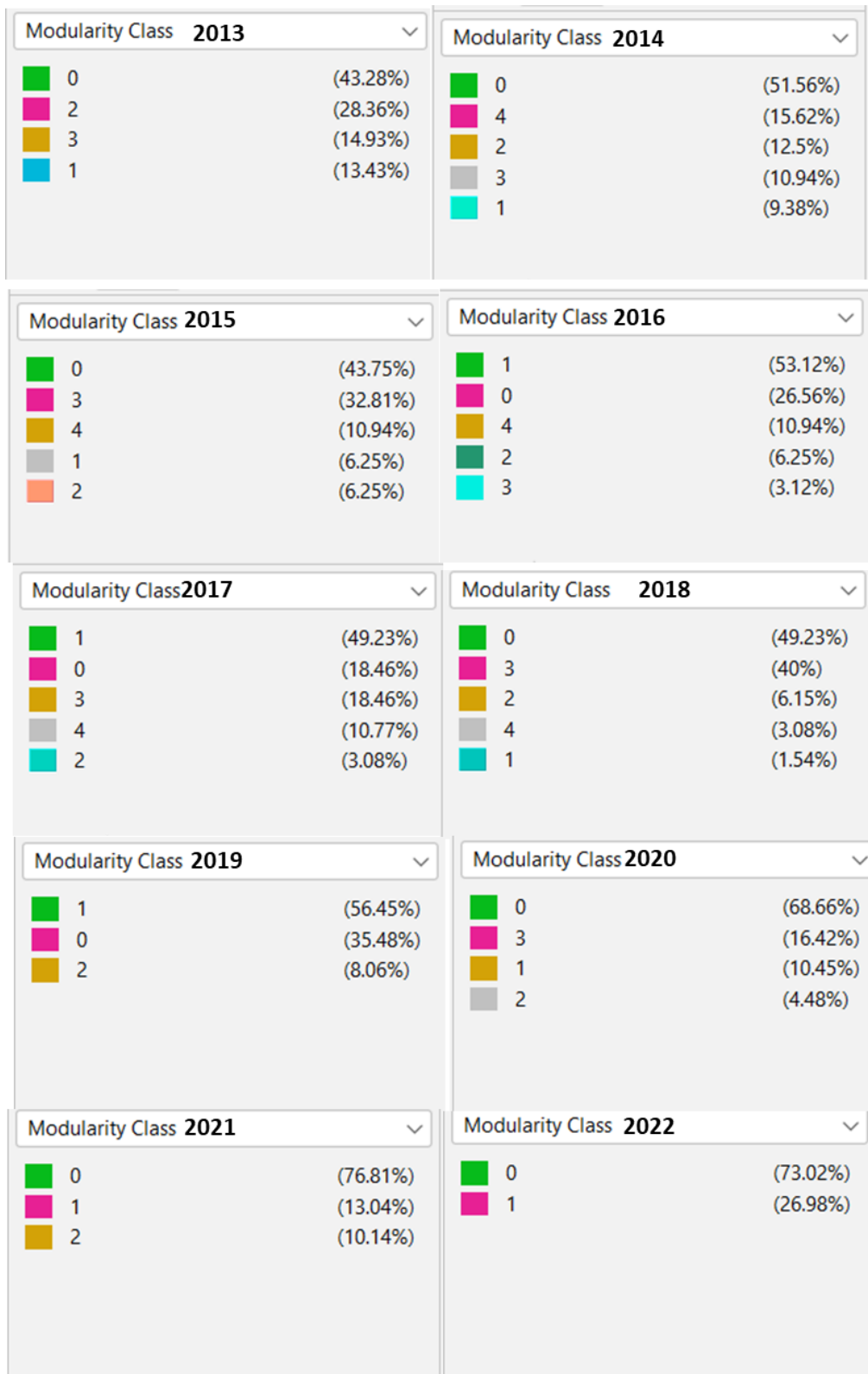


Figure 22 Communities in the copper ore network, 2013-2022

In 2021 and 2022, the trend towards a single dominant community continues, with Class 0 comprising an even more significant majority, more than 70% with a peak of 76% in 2021. This could suggest a reconfiguration of the network, where previously distinct trade communities have integrated, potentially reflecting new trade agreements, realignments in supply chains, or shifts in geopolitical alliances.

#### **4.4. Centrality and Community Structure Integration**

In this section, a combined analysis has been done mixing three different kinds of measures: out-degree centrality, weighted out-degree and a partition by modularity. In the following graphs, the colour of the nodes and edges denote the community to which the node belongs. The thickness of the edges represents the weighted out-degree; the thickest the edge, the higher the weighted out-degree. Finally, the size of the nodes represents the out-degree centrality. While the color of the communities varies per year only the biggest community of each year is represented in green color in order to have an easy and fast visualisation.

In the following graphs, there are four elements in the top pf each figure. “Year”, the year of analysis; “Modularity”, refers to the modularity of the network; “N°Comunities”, means the number of communities and, finally “P.C”, represent Peru’s clustering.

##### 2013: Foundational Networks and Emerging Roles

In the initial phase of the network analysis spanning from 2013, Peru emerges as a commanding presence, distinguished by significant out-degree centrality. This is visually represented by the size of its nodes within the network, illustrating a broad spectrum of export relationships. Concurrently, the pronounced thickness of the edges directed towards China signifies a high weighted out-degree, corroborating the substantial trade volumes between the two nations. This dual representation of node size and edge thickness establishes Peru's role as both a pivotal and voluminous exporter in the global copper ore trade, emphasizing its early dominance in the network characterized by four distinct communities.



Year: 2013 Modularity:0.231 N°Communities:4 P.C:0.257

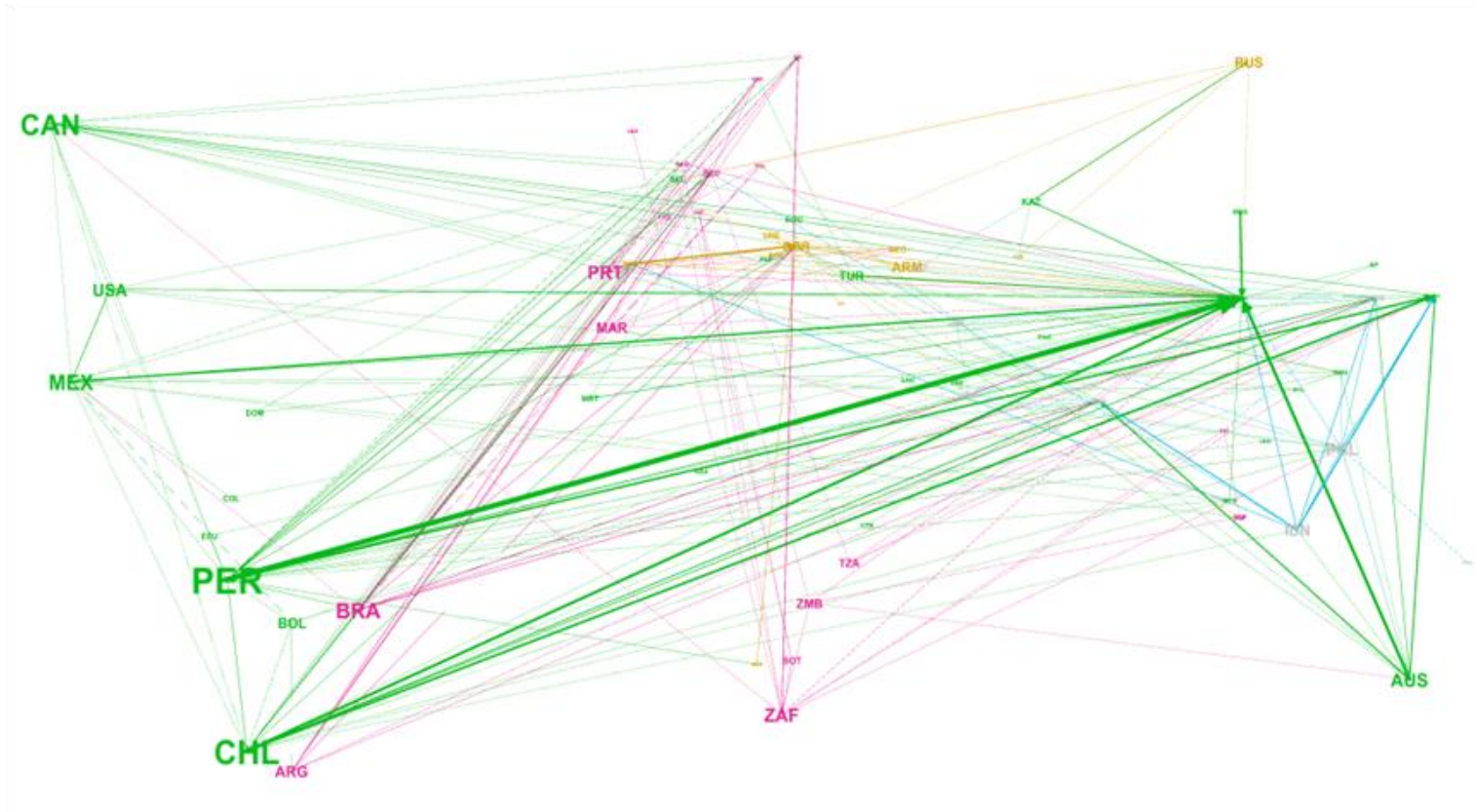


Figure 23 Copper ore trade network by out-degree, weighted-out degree and community, 2013

Chile starts the year with substantial trade connections, mirrored by the robustness of its nodes, which are comparable to Peru's in size and edge thickness, indicating a competitive export volume to significant partners like China. Brazil, Indonesia, Canada, and Australia are represented with smaller nodes, denoting fewer out-degree centrality, yet they hold notable positions within their respective communities, suggesting focused but significant trade relationships.

#### 2014: Growth and Diversification

With the addition of a fifth community, the network's complexity increases. Peru's slightly smaller nodes may indicate a slight dip in out-degree centrality, while still maintaining robust trade volumes, particularly with China. Chile's presence remains commanding within the network, possibly even intensifying its trade volumes as indicated by the pronounced edges, particularly those directed toward China. This year marks Brazil and Indonesia's noticeable growth, as their increased node sizes imply an expansion in their export activities. Canada and Australia maintain their established trade connections, with consistent centrality that underscores their importance in the global copper ore trade.

Despite the emergence of an additional community within the network, Peru maintains its strong position, as evidenced by its still significant node size. The slight decrease in the normalized weighted out-degree could indicate increasing competition or the beginning of a shift in trade dynamics.

#### 2015: Peak Intermediary Influence

The network retains five communities, but modularity decreases, suggesting closer inter-community trade. Peru's node size and edge thickness to China remain pronounced, although changes in the network structure could be impacting its role. Chile continues to cement its status as a primary exporter, with edges suggesting a robust weighted out-degree that may surpass other prominent trading nations. Meanwhile, Brazil and Indonesia's rising influence in the network becomes more evident, likely reflecting strategic developments in their export capacities. Canada and Australia's positions remain steady, indicative of their sustained roles in the global trade landscape, which are vital yet less dominant compared to the leading South American exporters.

Year: 2014 Modularity: 0.276 N°Communities: 5 P.C: 0.211

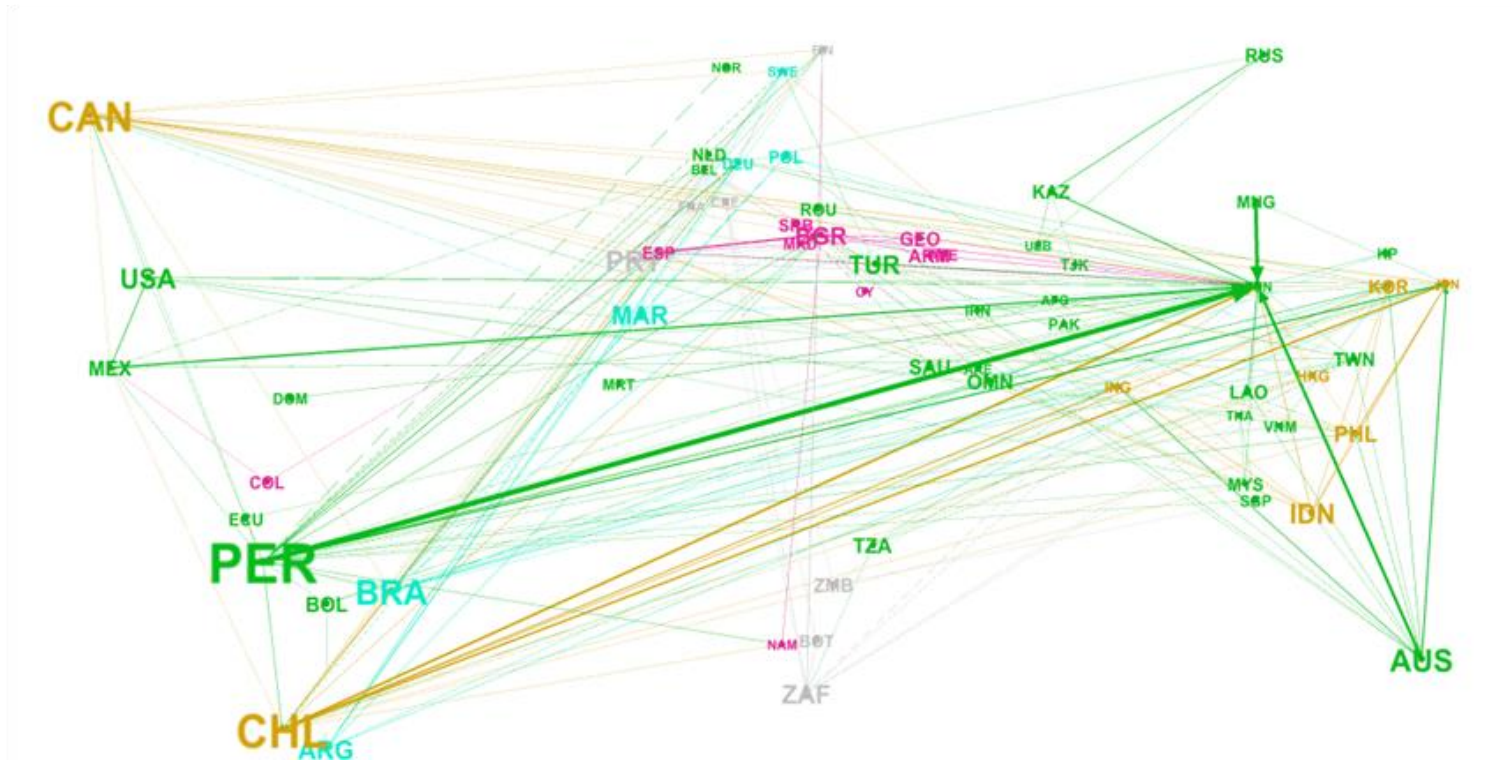


Figure 24 Copper ore trade network by out-degree, weighted-out degree and community, 2014

Year: 2015 Modularity:0.177 N°Communities:5 P.C: 0.243

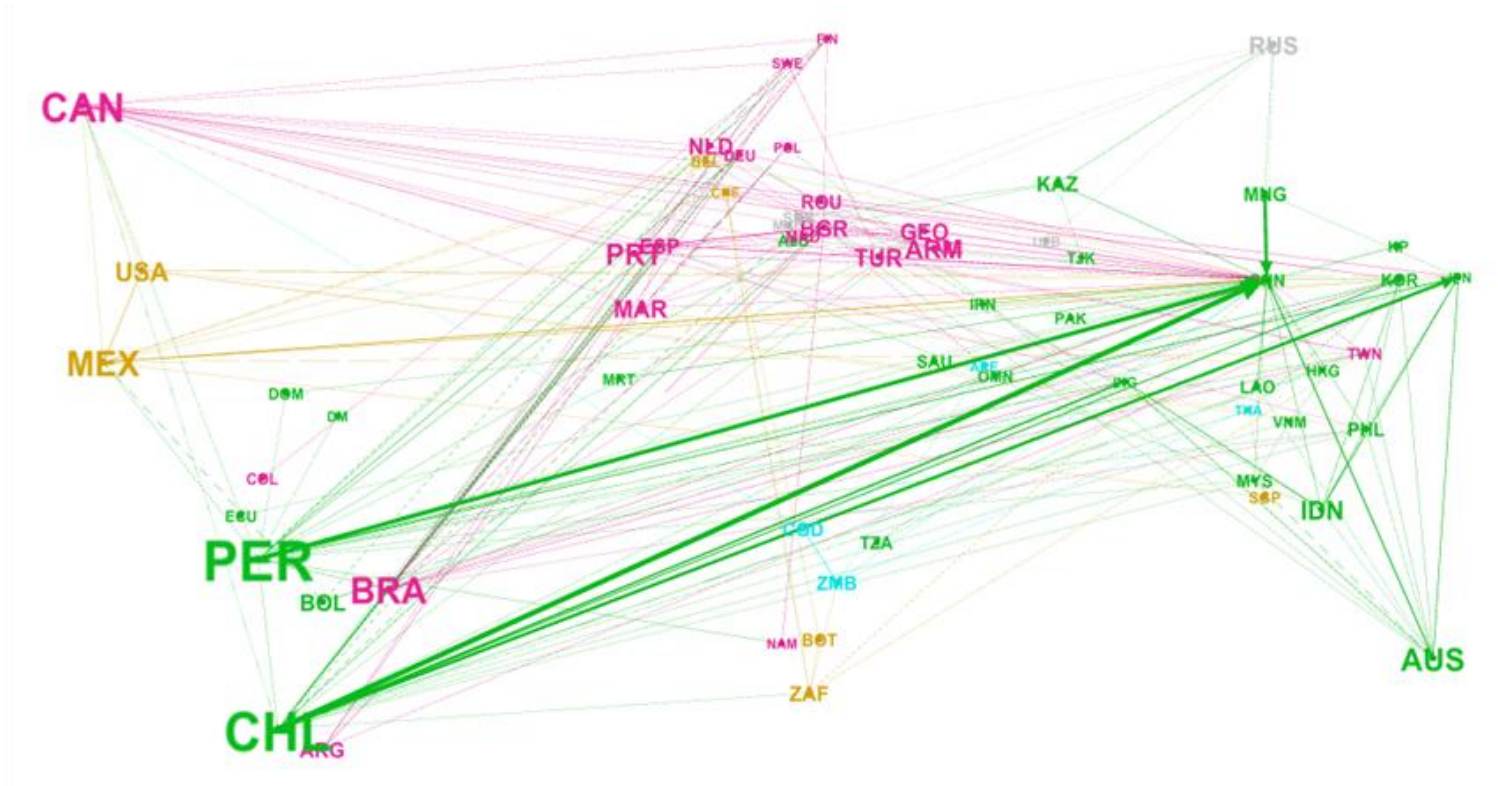


Figure 25 Copper ore trade network by out-degree, weighted-out degree and community, 2015

Peru's role as a trade intermediary peaks with an increase in betweenness centrality. This is a year of substantial influence for Peru, where it plays a central role in connecting various parts of the network, even as overall modularity decreases, suggesting a closer interconnection between communities.

#### 2016: Shifting Trade Dynamics

Despite continued modularity reduction, five communities persist, indicating stable but intensifying trade connections. During this period, Chile's trade centrality is potentially more pronounced, with its nodes and edges suggesting a solid hold over export volumes. Brazil and Indonesia appear to solidify their roles within the network further, hinting at an increased out-degree centrality. Canada and Australia possibly demonstrate growth in their centrality measures, reflecting an uptick in trade activity and suggesting a solidification of their positions within the network.

Peru's out-degree centrality remains high, reflecting diverse connectivity. However, the reduction in modularity indicates more integration across communities, which could mean Peru's intermediary role is being shared with other emerging nodes within the network.

#### 2017: Reinforcement of Existing Ties

Network modularity slightly increases, perhaps reflecting a reinforcement of trade blocs. Chile's network visualisation this year likely shows its unwavering dominance as a central trade hub, with dense connections within the network signalling high trade volumes. Brazil and Indonesia's trend of growth in their trade networks may continue, as both countries possibly see an increase in the thickness of their edges, denoting a greater weighted out-degree. Canada and Australia, while not as central as Chile, seem to maintain their significant roles, with steady trade links that are crucial to the network's diversity and stability.

Peru's trade centrality is highlighted by larger node size, but its dominant position is being contested, as seen by the edge variations. As the network begins to show signs of increasing modularity, Peru's position remains stable. Its centrality in terms of out-degree indicates continued strong export relationships, but the competitive landscape is intensifying, which may affect trade volumes.

Year: 2016 Modularity: 0.115 N°Communities:5 P.C: 0.275

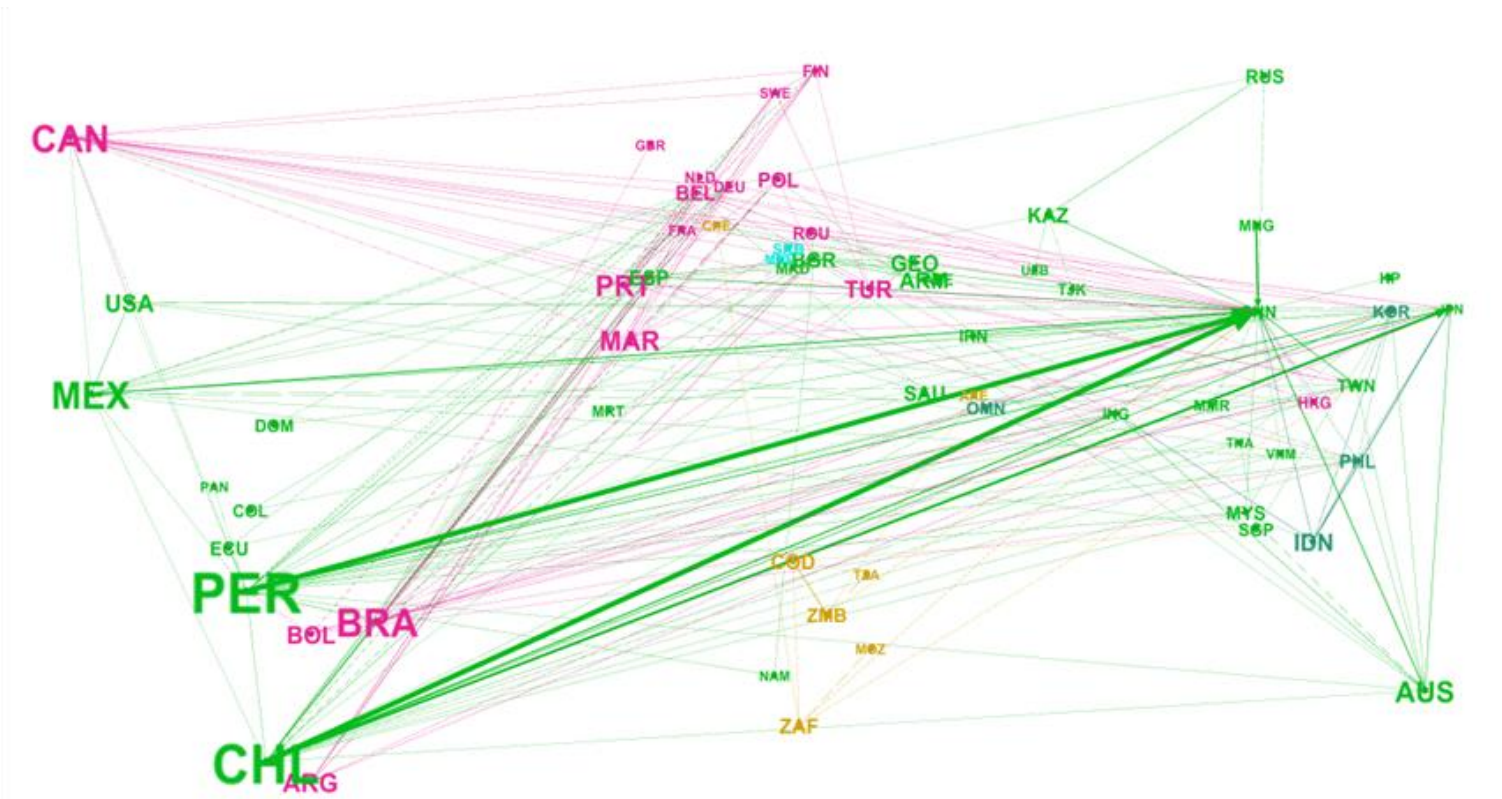


Figure 26 Copper ore trade network by out-degree, weighted-out degree and community, 2016

Year: 2017 Modularity: 0.155 N°Communities:5 P.C: 0.265

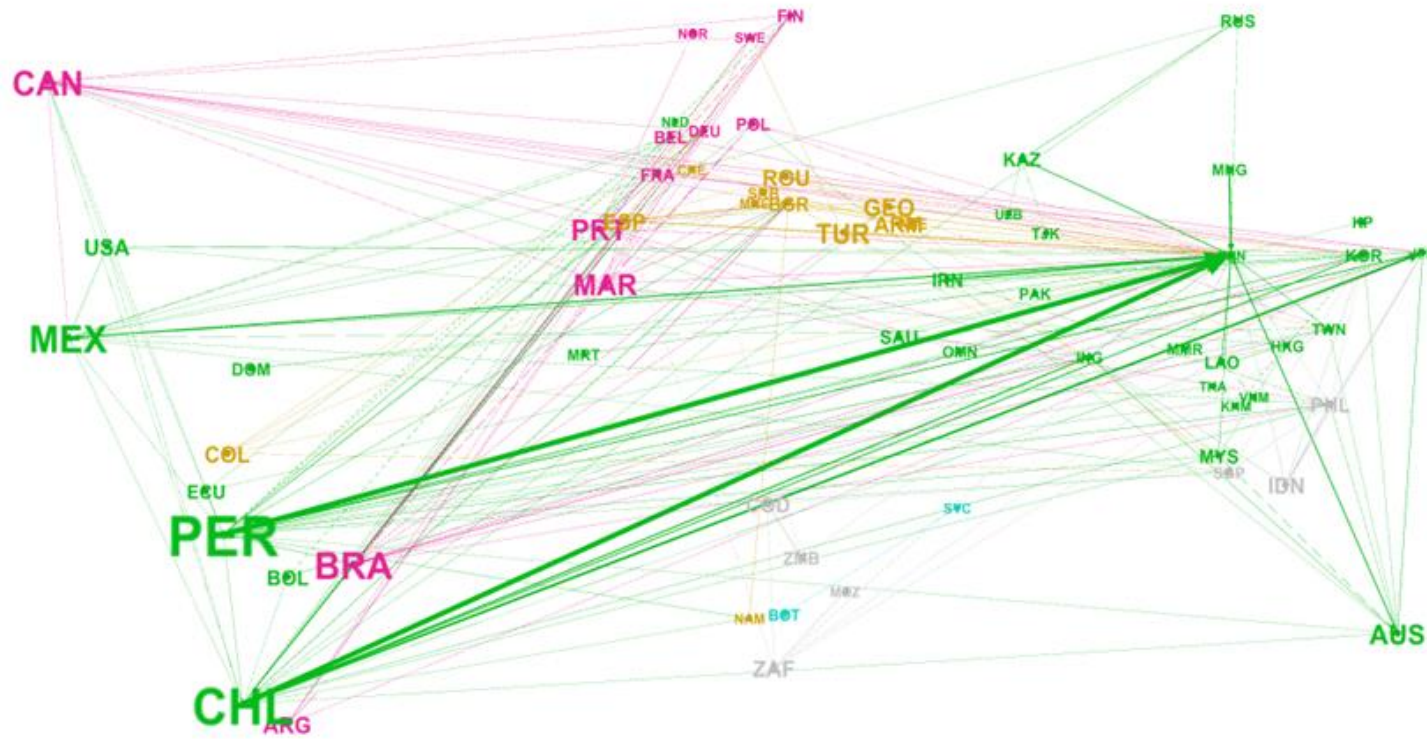


Figure 27 Copper ore trade network by out-degree, weighted-out degree and community, 2017

## 2018: Consolidation and Competition

With five communities still, the network seems to be consolidating. Chile's network position remains robust, with its well-established connections indicating a sustained or even growing influence in the global copper trade. The country's visual prominence in the network, through thick trade links, especially with significant partners, signals a high volume of exports. In contrast, Brazil and Indonesia's nodes, while still significant, do not exhibit the same level of thickness in their edges, suggesting a stable but less dominant trade volume compared to Chile. Canada and Australia demonstrate resilience in their trade relationships, maintaining their crucial roles in the network.

Peru's centrality, as indicated by node size, suggests robust trade activity, but the thinning edges to China could signal emerging competition from other nations. The modularity remains like in 2017, but Peru's centrality begins to decline. The edges thin out, suggesting a decrease in the weighted out-degree, which could be due to various factors, including market saturation or the rise of alternative suppliers.

## 2019: Community Integration

A reduction to three communities with increasing modularity hints at greater integration. Peru's node size indicates sustained out-degree centrality, but the network is likely becoming more competitive. This year shows Chile's continued prominence, with potentially expanding trade relationships as indicated by its consistently thick edges. Brazil and Indonesia's positions in the network reflect a steady presence, with their roles as exporters potentially benefiting from strategic trade policies or shifts in global demand. Canada and Australia's nodes indicate a persistent influence, maintaining their established connections within the network and reinforcing their importance to the stability of global copper ore trade.

The network sees a significant reduction in the number of communities. Peru is holding its ground, but the overall integration suggests that the network is becoming more competitive, with other countries potentially challenging Peru's role.



Year: 2018 Modularity: 0.133 N°Communities:5 P.C: 0.285

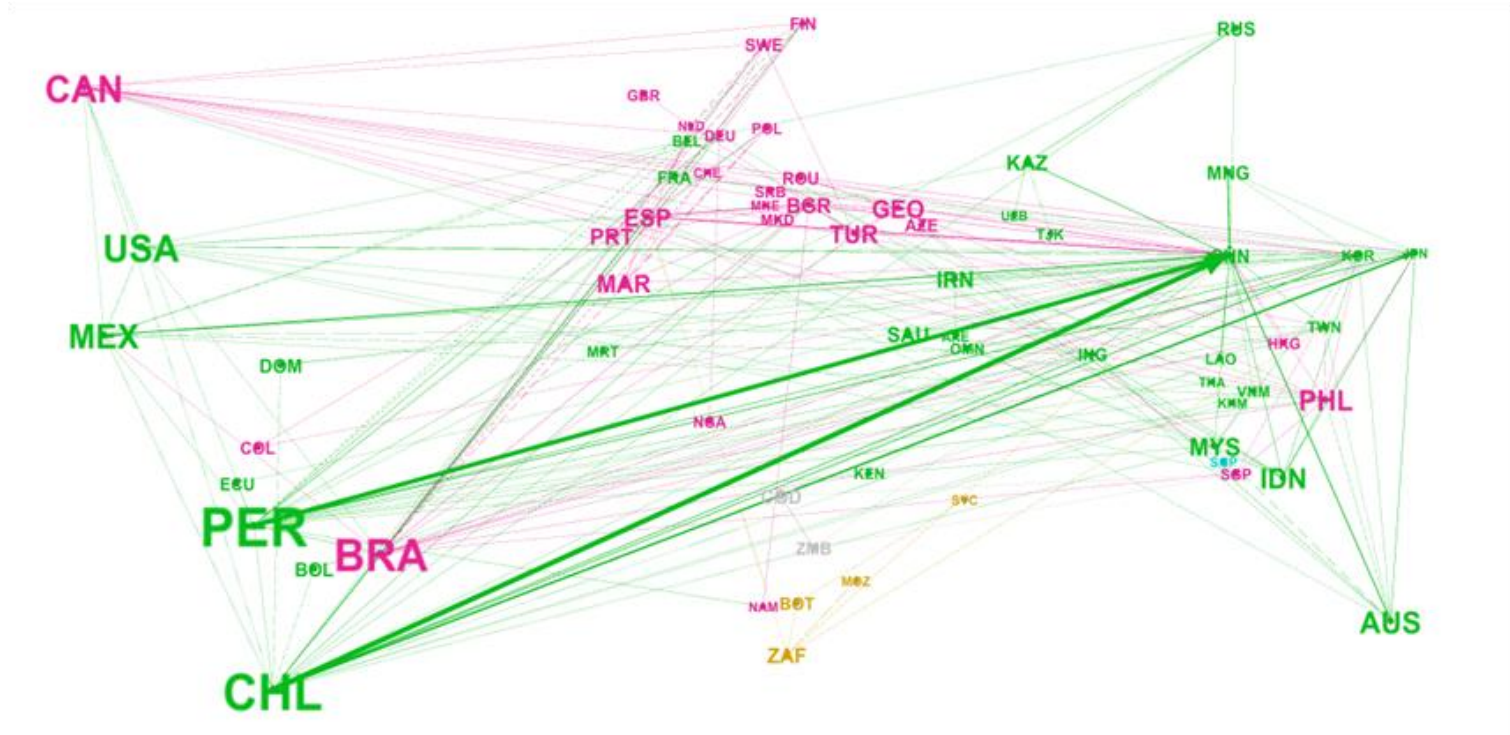


Figure 28 Copper ore trade network by out-degree, weighted-out degree and community, 2018

Year: 2019 Modularity: 0.119 N°Communities:3 P.C: 0.272

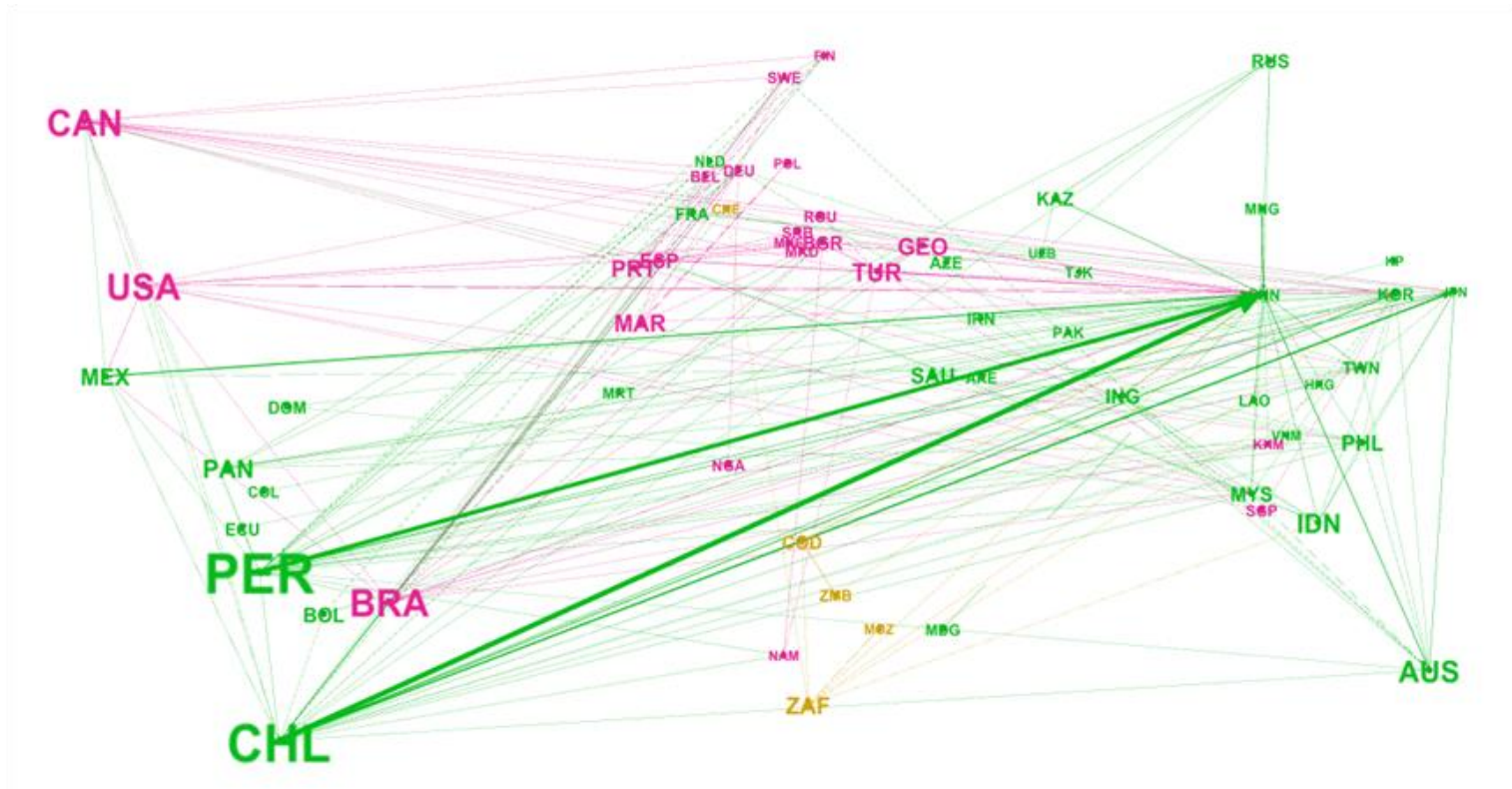


Figure 29 Copper ore trade network by out-degree, weighted-out degree and community, 2019

Year: 2020 Modularity:0.063 N°Communities:4 P.C: 0.283

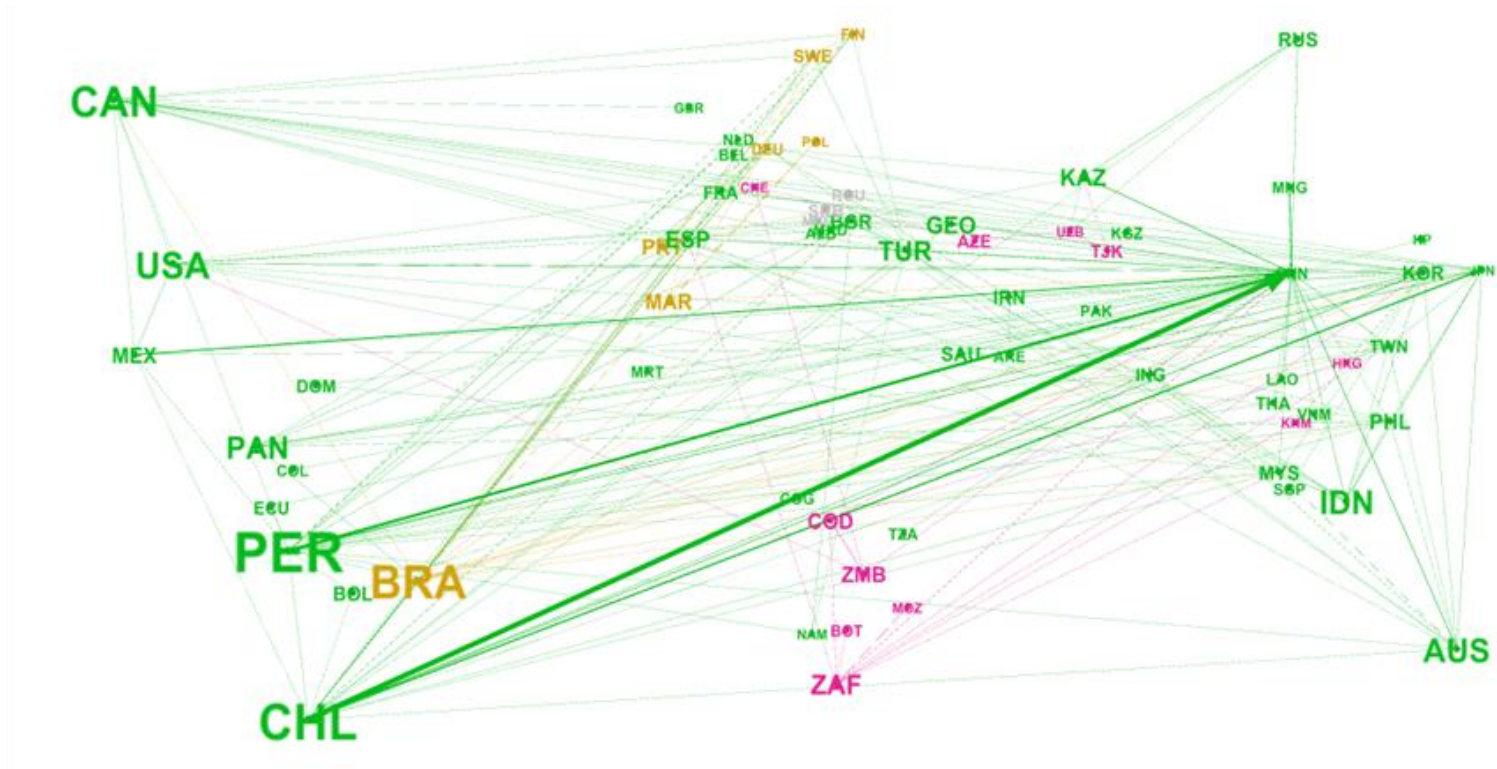


Figure 30 Copper ore trade network by out-degree, weighted-out degree and community, 2020

### 2020: Pandemic Disruption

Peru's smaller nodes and thinner edges denote a significant impact on its trade activity, aligning with the global economic slowdown. COVID-19 disrupts the global economic landscape, and Peru's trade network is not spared. The centrality measures for Peru decrease, as reflected in thinner edges and smaller node sizes, indicative of both reduced trade volume and influence.

### 2021: Recovery and Realignment

The number of communities decreases to three, with a slight increase in modularity, suggesting some recovery. In the post-pandemic recovery phase, Chile's trade links may begin to show signs of recovery, with an increase in the size of its nodes and the thickness of its edges. Brazil and Indonesia possibly continue to adapt to the changing global conditions, with their network visualisations indicating a degree of recovery or strategic realignment in their trade relations. Canada and Australia's nodes may also reflect a rebound as they re-establish and potentially enhance their positions within the network.

Peru's larger nodes indicate a rebound in its out-degree centrality, pointing to a partial recovery of its trade position. There is a modest increase in modularity and a reduction in the number

of communities. Peru's node size increases, pointing to a recovery in its out-degree centrality, showing resilience and an ability to bounce back from the previous year's downturn.

### 2022: Establishing a New Equilibrium

With only two communities and a slight modularity increase, the network is possibly establishing a new equilibrium. By 2022, the network visualisation possibly indicates that Chile, Canada, and Australia are navigating towards a new equilibrium within the global copper ore trade. Chile's continued thickness in trade links suggests an enduring influence, while Brazil and Indonesia may consolidate their positions within the network in the global trade dynamics.

Year: 2021 Modularity: 0.067 N°Communities:3 P.C: 0.346

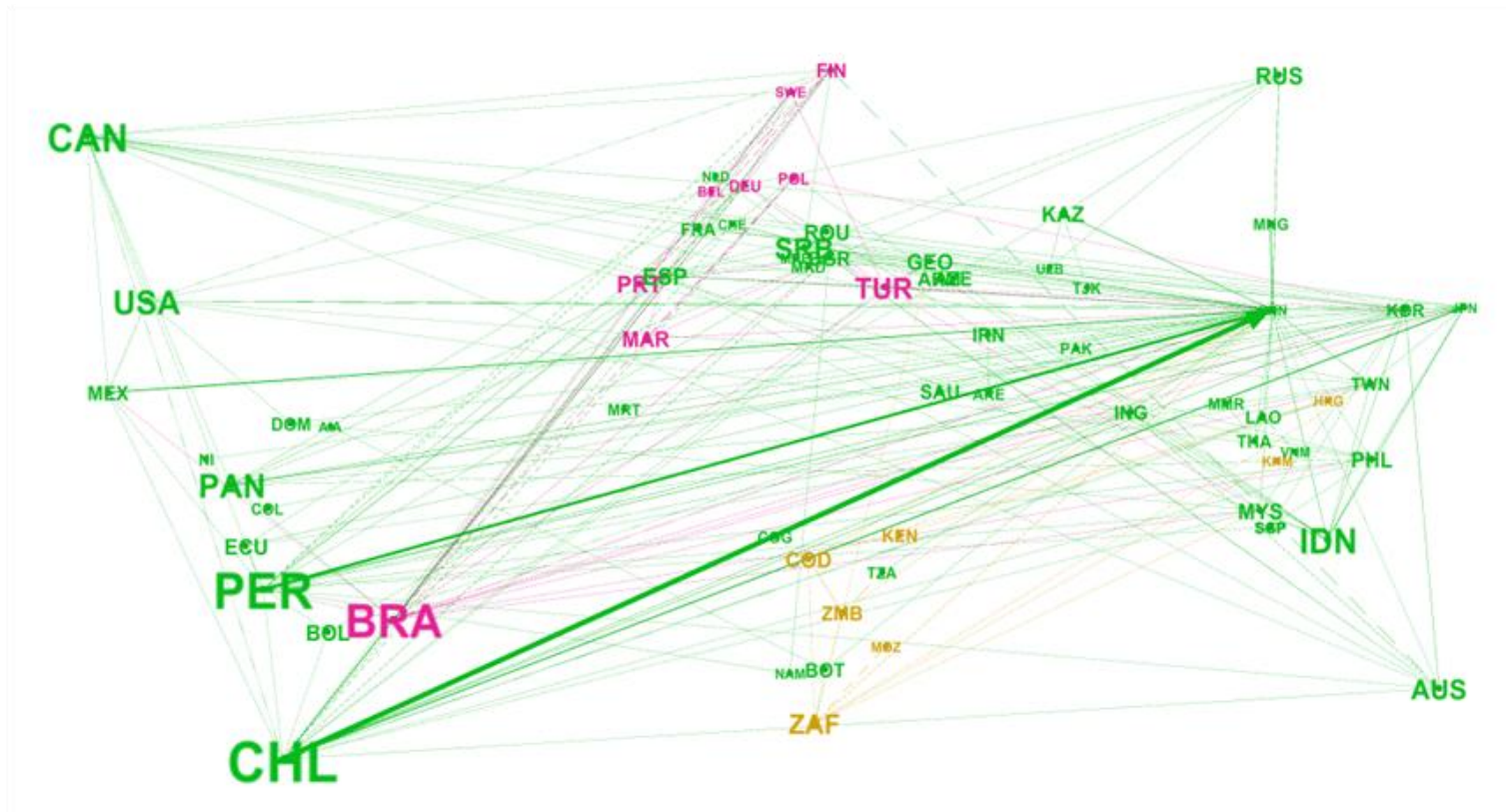


Figure 31 Copper ore trade network by out-degree, weighted-out degree and community, 2021

Year: 2022 Modularity: 0.076 N°Communities:2 P.C: 0.332

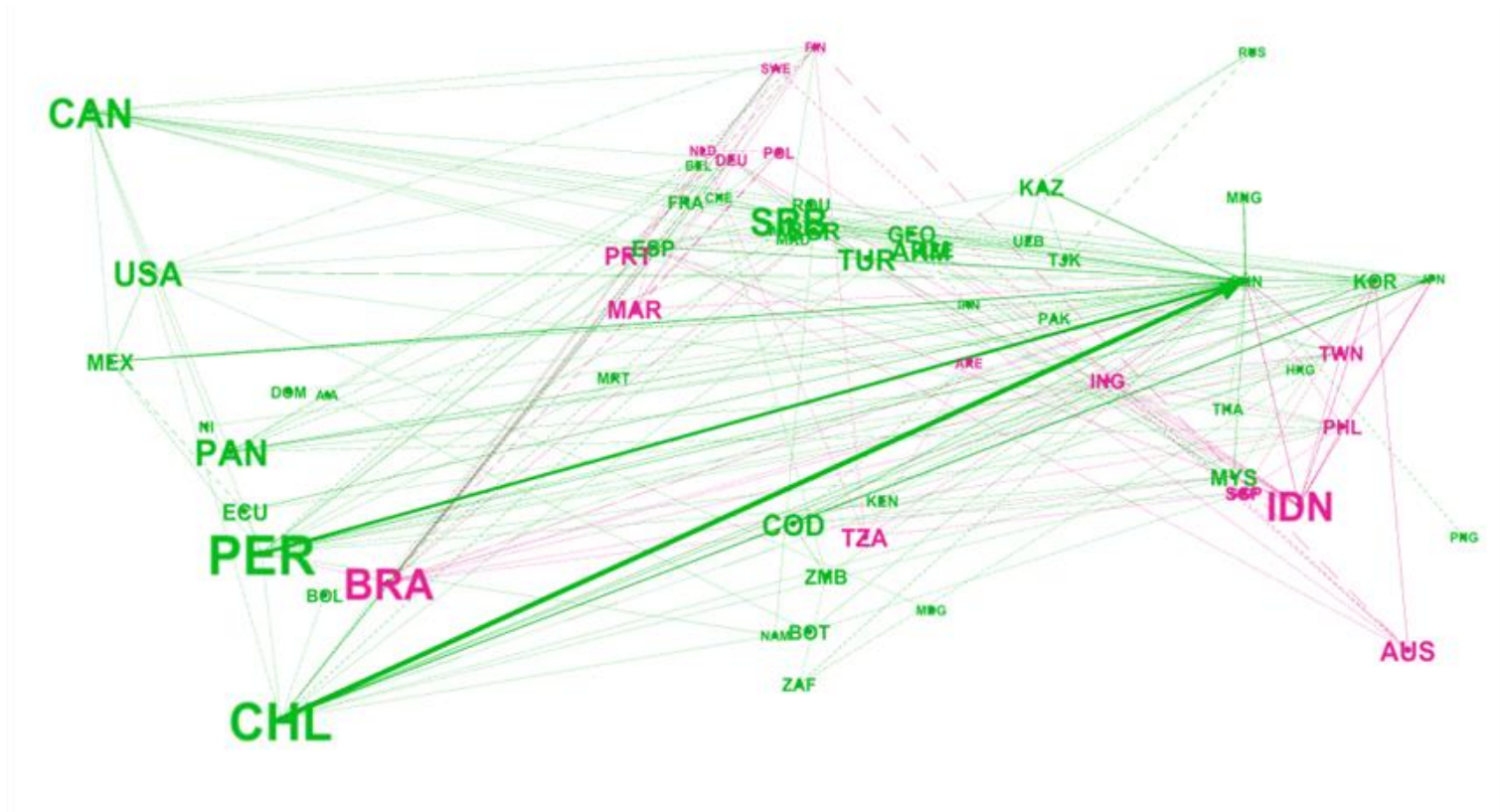


Figure 32 Copper ore trade network by out-degree, weighted-out degree and community, 2022

Peru's node size and edge thickness to China are increasing, reflecting a resurgence in its trade centrality and volume, although not yet at pre-pandemic levels. With the network consolidating into just two communities, Peru's centrality, as shown by the size of its nodes, continues to improve. This suggests that Peru is regaining some of its lost ground and is adapting to the post-pandemic trade environment, although it has not yet fully returned to its pre-pandemic level of influence.

Indonesia begins with a modest network presence but gains prominence as its nodes enlarge, reflecting an increase in out-degree centrality. The country's thickening trade links, particularly in the latter years, suggest a strategic growth in its export volume. Indonesia's network position strengthens, even amid the disruptions caused by the pandemic, positioning it as a rising intermediary and a significant exporter in the copper ore trade network.

A similar case is Brazil's trajectory in the network, which suggests a gradual increase in its export activities, as indicated by growing node sizes through the years. Initially a less central participant, Brazil's increasing edge thickness overtime points to an expansion in trade volumes. Despite global economic fluctuations, Brazil demonstrates resilience and maintains its presence, hinting at strategic adaptations to remain competitive in the copper ore market.

In 2021 and 2022, the presence of a single dominant community that captures more than 70% of the market signifies a concentration of power and influence within the network.

This centralisation could be attributed to a few significant players, which is characteristic of an uneven distribution of trade activities. This indicates a more consolidated market with a few key players controlling a significant share of the copper ore trade. Peru, Chile, and Canada have become the leaders of the biggest community. In the smaller one, Indonesia and Brazil lead it.

#### **4.5. Key findings**

- From 2013 to 2022, Peru has upheld a robust position as a copper exporter, consistently maintaining a Normalised Out-Degree above 0.27. This steadfast metric indicates that Peru has sustained direct export relationships with a significant portion of the countries in the network, asserting its role as a principal exporter within the global copper ore trade network.

- Starting with a Normalised Weighted Out-Degree of 1, indicative of Peru's strong export ties and high export values, the country witnessed fluctuations over the subsequent years. Despite these variations, Peru's influence within the network remains substantial, reinforcing its status as a significant copper ore exporter and demonstrating the country's resilience in maintaining strategic export relations.
- Peru's notable betweenness centrality within the directed network accentuates its role as an influential intermediary, facilitating connections across the copper ore trade network. This substantial betweenness centrality not only reflects Peru's ability to control and direct trade flows but also its strategic acumen in reinforcing trade patterns, thereby solidifying its influential status.
- The impact of the COVID-19 pandemic resulted in a partial diminution of Peru's power within the network. However, a visible recovery in 2022, although not fully restoring pre-pandemic levels, points to Peru's tenacity. The risk remains that other countries, such as Indonesia and Brazil, may capitalise on any vacuums in network influence, highlighting the competitive nature of the trade.
- The declining modularity values observed suggest that over time, the network's structure has increasingly homogenised. This transition to fewer distinct communities signifies a more interconnected and integrated network, with countries across different regions engaging more directly in trade relationships.
- In 2021 and 2022, the emergence of a single dominant community, encompassing more than 70% of the market, signifies a notable centralisation of power. This trend suggests a strategic consolidation of the copper ore trade, with a few significant players exerting substantial control over a significant share of the trade volume.



- Peru's clustering coefficient experienced notable growth, indicating an enhanced interconnectedness among its trading partners. This development underscores Peru's pivotal role as a central hub for copper ore trade, with its trade partners not only engaging with Peru but also forming denser interconnections, reflecting a more cohesive network structure.
- Indonesia and Brazil emerge as leaders within their respective communities, underscoring their progressive roles throughout the network. Their increasing centrality indicates strategic positioning and growing influence within the copper ore trade, confirming the dynamic nature of global trade relations.

## **Chapter 5 Conclusions and Policy Implications**

### **5.1. Conclusions**

This study meticulously examines the evolution of Peru's role as a premier copper ore exporter and its intricate interplay within the global trade network over the past decade. The findings provide a multifaceted view of Peru's position and strategic interactions in the global copper ore market.

First, despite the fluctuations in export values, Peru maintained a strong and consistent position as a critical copper exporter from 2013 to 2022. Its resilient role in the global copper ore trade is evident through its high betweenness centrality and normalised out-degree, signifying its strategic influence and control in the trade network.

Second, the decline in Peru's dominance since 2020, mainly due to global disruptions, presents a challenge to its longstanding position. While recovery efforts in 2022 show promise, they have yet to reach pre-pandemic levels. The increasing prominence of Indonesia and Brazil indicates a potential shift in the power balance of the network.

Third, the global copper ore trade network has become increasingly interconnected and integrated with declining modularity values and the emergence of a dominant community. This trend reflects market centralisation in which a few key players, including Peru, have a significant influence.

Fourth, Peru's growing clustering coefficient suggests an enhanced role as a central hub, fostering increased interconnectedness among its trading partners. However, the growing roles of Indonesia and Brazil mark a shift, indicating that these countries are becoming increasingly vital to the network, and could reshape future trade dynamics.

## 5.2. Policy Implication

The critical role of Peru in the global copper industry, as highlighted by its substantial share of the nation's exports and the untapped potential of its mining reserves, requires a strategic and multifaceted policymaking approach. This section outlines comprehensive policy recommendations derived from the study's findings.

- Resilience and Risk Mitigation

COVID-19 has significantly impacted the Peruvian mining sector. Risk mitigation strategies must be formulated to address internal and external variables such as social conflicts and natural phenomena, for example, El Niño, which could disrupt mining activities and copper trade.

As copper exports constitute a significant portion of Peru's trade balance, the resilience of this sector is of national importance. Recognising that only a small fraction of Peru's mining concessions are currently active, policies should support the exploration and development of these areas. This can increase production capacity and provide a buffer against economic shocks.

The National Policy for Disaster Risk Management<sup>14</sup> by 2050 issued by the Peruvian Government only mentions the word "mining" once in the main body of the Policy, and the text refers only to illegal mining.

- Diversification of Trading Partners

Peru's reliance on China as a primary export destination for copper, which accounts for over 70% of its exports, is a significant risk factor, especially considering the volatile nature of international trade relations. To mitigate this risk, it is imperative to expand and diversify Peru's export markets. Engaging with emerging economies and strengthening trade relations with other significant importers, such as Japan and Korea, which already play a role in Peru's copper export network, is crucial. This strategy should also consider establishing new trade partnerships within South America, leveraging the fact that the western part of the continent, including Chile and Peru, contributes 40% of the global copper output.

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<sup>14</sup> D.S 038-2021-PCM, "National Policy for Disaster Risk Management", issued by the Presidency of the Council of Ministers of Peru, dated March 01, 2021.

The analysis identified countries that participated in communities isolated from Peru. Thus, the Peruvian government should focus on entering these markets. For example, Peru has a trade agreement with European Free Trade Association (EFTA)<sup>15</sup>, including Norway, which has facilitated the export of significant minerals such as gold and copper to EFTA member countries. However, Peru lacks trade agreements with Finland, Sweden, and Denmark. This presents challenges and opportunities for Peru, limiting direct access to these markets under preferential trade terms but presenting a potential area for growth and exploration in Peru's foreign trade policy. Expanded trade relations with Nordic countries can benefit the mining sector, open new markets for mineral exports, and foster economic development.

By contrast, Peru and Indonesia are significant players in the global copper market and are often positioned as competitors. With its substantial copper-mining operations, Indonesia challenges Peru's position as a critical copper exporter. This competitive landscape underscores the complex interactions in which two nations can explore collaborative trade opportunities while competing in the same sector.

Recently, advancements toward establishing formal trade relationships between Peru and Indonesia<sup>16</sup> have been made. The Ministry of Foreign Trade and Tourism of Peru (MINCETUR) announced that both countries had agreed to initiate negotiations for commercial agreements. Such bilateral trade agreements could be strategic milestones for Peru, potentially opening avenues for cooperation beyond the copper industry.

Engaging in trade negotiations with Indonesia, despite its competitive stance on copper exports, signals Peru's proactive approach. This reflects an understanding of the benefits of diversified trade relationships and the potential for mutual growth. This potential agreement could lead to broader economic cooperation, offering Peru a platform to access other Asian markets and mitigate its overreliance on copper exports. Moreover, it could foster a balanced trade relationship with Indonesia, strengthening Peru's position in the global economy by tapping into new markets and sectors.

- **Strengthening Diplomatic and Trade Relations**

The dominance of South America in the copper market, especially contributions from Peru and Chile, suggests the potential for increased regional collaboration. Both nations could enhance their standing and influence in the global copper trade by aligning their diplomatic and trade strategies. Active participation in international commodity forums and the

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<sup>15</sup>European Free Trade Association. <https://www.efta.int/>

<sup>16</sup> <https://www.gob.pe/institucion/mincetur/noticias/768092-peru-e-indonesia-acordaron-iniciar-negociaciones-para-un-acuerdo-comercial>

establishment of common agendas in trade negotiations can strengthen a region's economic cloud. Diplomatic efforts must cover newly emerging leaders such as Indonesia and Brazil.

When examining the impact of the Ministry of External Affairs (MRE) on the facilitation of mining investments, it is crucial to highlight the significance of establishing a cohesive strategy with the Ministry of Energy and Mines (MINEM), which remains absent (Valdivia, 2021). Consequently, diplomatic efforts tend to respond to investor demand, while promotional activities involving Peru's participation are primarily organised by chambers of commerce. Similarly, although a certain level of concordance exists in the collaboration between MINEM and MRE, there is a conspicuous absence of a comprehensive and deliberate framework for addressing mining-related matters. This gap underscores the fact that the overarching state policy regarding mining is still being formulated and articulated. Therefore, to address topics that fall primarily under the jurisdiction of the MINEM initiative, it is essential to establish substantial coordination with the MRE. This collaboration will enable the development of a mining policy that transcends sectoral boundaries to become a comprehensive state policy. Additionally, it facilitates proactive efforts to promote investments undertaken by OSEs. Furthermore, an efficient projection of Peru's image as a Mining Country can be achieved through this collaborative approach.

- Support for Research and Innovation

Peru's status as the second-largest global producer of copper and its vast reserves suggest its immense growth potential. To capitalise on this, the government should foster an environment conducive to innovation, particularly in extraction and processing technologies. Incentives include tax breaks for companies investing in R&D, collaboration with international mining firms, and partnerships with academic institutions to drive sustainable practices.

In Peru, there are some private R&D initiatives focused on the mining sector, such as the Mining Innovation Hub<sup>17</sup> and the Southern Mining Cluster<sup>18</sup>. The Mining Hub, an association promoting innovation and collaboration within the mining industry, aims to foster an environment that supports innovative thinking, minimises effort, and facilitates expeditious problem-solving, promoting the mining sector as a highly innovative industry. At the same time, the Mining Cluster of Southern Peru (CMSP) is an initiative that has been endorsed by the CAF<sup>19</sup>, the Development Bank of Latin America, and the Chamber of Commerce and

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<sup>17</sup> <https://hubinnovacionminera.pe/>

<sup>18</sup> <https://clusterminero.linkminers.com/inicio>

<sup>19</sup> Development Bank of Latin America and The Caribbean. <https://www.caf.com/>

Industry of Arequipa (CCIA). In the second initiative, the Regional Government participates; however, in the first initiative, there is no public participation at all.

- **Data and Analysis for Strategic Decision Making**

A data-driven approach to managing Peru's copper resources and trade is essential. This should involve the development of sophisticated analytic capabilities to monitor global market trends, track competitor strategies, and adapt to changing demand dynamics. By investing in robust systems for data collection and analysis, Peru can maintain its competitive edge and respond proactively to global market fluctuations as a preventive direction.

An example of a successful government mining institution is the Chilean Copper Commission (COCHILCO), a government-owned organisation established in 1976 that plays a crucial role in the country's mining sector, particularly in the copper industry. This organisation advises the government on copper-industry policies, monitors the global market, and promotes sustainable development. COCHILCO provides accurate information on the copper market as well as studies and recommendations for exploration, exploitation, environmental issues, and resource management. It also forecasts the future copper market trends and ensures compliance with environmental and safety standards. By promoting sustainable practices, COCHILCO has significantly contributed to Chile's economic development and underpins the strategic importance of Cu in national and global economies. Even when Peru created the General Directorate of Mining Promotion and Sustainability under Peru's Ministry of Energy and Mines in 2018, the directorate could not be compared with the entire institution as COCHILCO.

These policies are intended to ensure the sustainable development of Peru's copper industry, improve its global trade position, and bolster its economic stability. Successful implementation of these recommendations requires coordinated efforts among government agencies, industry stakeholders, and international partners, all working toward a resilient and prosperous future for Peru's copper trade.

### **5.3. Limitations and Future Research**

While this research provides a detailed analysis of Peru's role in the global copper ore trade network, it is essential to recognise its limitations, which also open up various avenues for future research.

### *5.3.1. Limitations*

- a) **Incomplete Data for 2022:** The absence of complete data for small countries in TradeMap for 2022 may lead to an incomplete understanding of the most recent market dynamics. Consequently, the analysis for this period may not have fully captured the impact of recent global economic events on Peru's copper export sector.
- b) **Temporal Scope:** A ten-year analytical timeframe, although significant, is relatively short for capturing the full spectrum of the cyclical nature of the commodities market and the strategic shifts in global trade relations that unfold over extended periods.
- c) **Data Availability for Small Countries:** The exclusion of data for smaller countries from TradeMap potentially overlooks the nuances and contributions of these nations within the global copper trade network, which may influence broader market dynamics.
- d) **Focus on Export Volume:** This study focuses on the volume of copper exports without accounting for price fluctuations. This does not reflect the financial implications of changes in global copper prices, which can significantly affect the economic impact of trade.
- e) **Lack of Social and Environmental Considerations:** This study did not address the social or environmental impacts of copper mining and export. These aspects are critical to a holistic understanding of the sustainability of the copper trade and its broader implications.
- f) **Concentration of Ore and Concentrates:** The study is limited to the examination of ore and concentrates and excludes other stages of the copper production process, such as refining and recycling, which are essential elements of the overall value chain.

### *5.3.2. Future Research*

Based on the limitations and issues identified in the copper ore mining sector, Peruvian officers and academics should focus on the following research topics:

- a) **Risk Management in Mining:** This study explores advanced methodologies for risk assessment and mitigation in Peru's mining sector. This can involve the development of predictive models to forecast potential disruptions due to social conflicts or natural phenomena such as El Niño. This research also proposes comprehensive risk management frameworks that integrate internal operational risks and external environmental and

geopolitical risks. Collaboration with geological and environmental experts can enhance the predictive accuracy of these models.

- b) **Trade Diversification Strategies:** This area of research focuses on identifying new markets for Peru's copper exports. This could involve an in-depth market analysis examining the economic, political, and logistical factors affecting trade relationships. Studies can also evaluate the impact of existing trade agreements and explore the potential for new agreements using trade theory and economic modelling. This research could also include scenario planning to assess the potential outcomes of various diversification strategies.
- c) **Collaboration and Competition in Global Markets:** This study analyses the competitive and collaborative dynamics between Peru and other major copper-exporting countries. It examines case studies on successful collaborations in similar contexts, draws lessons from competitive strategies, and proposes models for cooperative competition (coopetition) in the copper market. This research could also explore strategic alliances that benefit both parties, such as joint ventures or trade agreements.
- d) **Economic Analysis of Copper Price Fluctuations:** This study focuses on the economic implications of copper price volatility in the Peruvian economy. Econometric modelling should be used to understand the relationship between global copper prices and Peru's national income, trade balance, and overall economic health. This analysis could also include forecasting models to predict future price trends and their potential impact on the Peruvian economy.
- e) **Comprehensive Value Chain Analysis:** This study thoroughly examines the entire copper production process in Peru, from mining and extraction to refining and recycling. This study assesses the economic contribution of each stage and identifies opportunities for value addition and efficiency improvement. This could involve quantitative production data analysis and qualitative technological and operational practice assessments.

**Data Analytics for Strategic Decision-Making:** This research area focuses on developing advanced data analytics techniques to guide strategic decision-making in Peru's copper sector. This could involve the creation of predictive models and analytical tools to monitor global market trends, track competitor strategies, and respond to demand shifts. This research could also explore the integration of big data and machine learning to enhance decision-making processes in the mining sector.



Each of these research areas aims to provide in-depth insights and strategic recommendations to enhance Peru's copper industry's resilience, competitiveness, and sustainability in the global market.

By addressing these limitations and exploring the areas indicated for future research, a more comprehensive and holistic understanding of Peru's copper sector can be achieved, allowing for the development of robust strategic responses to the ever-changing dynamics of the global copper market.

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## Appendix

### Appendix 1: Central Degree Results

Country ID	Label	Year	In-Degree	Out-Degree	Degree	Weighted In-Degree	Weighted Out-Degree	Weighted Degree
Albania	ALB	2013	0	1	1	0	38	38
Argentina	ARG	2013	1	7	8	5	395	400
Armenia	ARM	2013	0	6	6	0	174	174
Australia	AUS	2013	2	9	11	12	2152	2164
Azerbaijan	AZE	2013	0	2	2	0	3	3
Belgium	BEL	2013	5	2	7	93	2	95
Bolivia Plurinational State of	BOL	2013	0	6	6	0	48	48
Botswana	BOT	2013	0	3	3	0	95	95
Brazil	BRA	2013	3	11	14	259	853	1112
Bulgaria	BGR	2013	16	5	21	1359	228	1587
Canada	CAN	2013	3	16	19	21	401	422
Chad	TD	2013	0	1	1	0	6	6
Chile	CHL	2013	4	19	23	170	2548	2718
China	CHN	2013	40	0	40	7121	0	7121
Colombia	COL	2013	0	2	2	0	3	3
Cyprus	CY	2013	1	0	1	1	0	1
Dominican Republic	DOM	2013	0	2	2	0	55	55
Ecuador	ECU	2013	0	2	2	0	10	10
Finland	FIN	2013	7	0	7	456	0	456
France	FRA	2013	0	1	1	0	2	2
Georgia	GEO	2013	2	2	4	13	124	137
Germany	DEU	2013	10	2	12	840	47	887
Hong Kong, China	HKG	2013	3	0	3	9	0	9
India	IND	2013	9	2	11	1339	25	1364
Indonesia	IDN	2013	4	7	11	63	1454	1517
Iran Islamic Republic of	IRN	2013	0	3	3	0	83	83
Japan	JPN	2013	10	0	10	2636	0	2636



Kazakhstan	KAZ	2013	2	3	5	7	536	543
Kenya	KEN	2013	0	1	1	0	1	1
Korea Democratic People's Republic of	KP	2013	1	1	2	3	25	28
Korea, Republic of	KOR	2013	13	2	15	1030	10	1040
Macedonia North	MKD	2013	0	1	1	0	52	52
Malaysia	MYS	2013	4	1	5	17	81	98
Mauritania	MRT	2013	0	2	2	0	187	187
Mexico	MEX	2013	6	11	17	229	684	913
Mongolia	MNG	2013	0	1	1	0	650	650
Morocco	MAR	2013	0	6	6	0	69	69
Namibia	NAM	2013	2	0	2	164	0	164
Netherlands	NLD	2013	5	1	6	72	57	129
Nigeria	NGA	2013	0	1	1	0	1	1
Oman	OMN	2013	6	2	8	76	30	106
Pakistan	PAK	2013	0	1	1	0	2	2
Papua New Guinea	PNG	2013	1	0	1	8	0	8
Peru	PER	2013	7	21	28	53	3813	3866
Philippines	PHL	2013	8	8	16	276	448	724
Poland	POL	2013	4	0	4	80	0	80
Portugal	PRT	2013	0	9	9	0	328	328
Romania	ROU	2013	0	2	2	0	45	45
Russian Federation	RUS	2013	1	6	7	280	28	308
Saudi Arabia	SAU	2013	0	1	1	0	40	40
Serbia	SRB	2013	1	2	3	5	4	9
Singapore	SGP	2013	3	0	3	17	0	17
South Africa	ZAF	2013	2	9	11	98	261	359
Spain	ESP	2013	10	2	12	535	729	1264
Sweden	SWE	2013	8	0	8	204	0	204
Switzerland	CHE	2013	7	0	7	34	0	34
Taipei, Chinese	TWN	2013	8	1	9	88	1	89
Tanzania United Republic of	TZA	2013	0	4	4	0	13	13
Thailand	THA	2013	4	0	4	7	0	7
Türkiye	TUR	2013	0	5	5	0	427	427
United Arab Emirates	ARE	2013	0	1	1	0	1	1

United Kingdom	GBR	2013	1	0	1	1	0	1
United States of America	USA	2013	3	8	11	30	400	430
Uzbekistan	UZB	2013	2	0	2	9	0	9
Viet Nam	VNM	2013	1	0	1	3	0	3
Zambia	ZMB	2013	0	5	5	0	52	52
Afghanistan	AFG	2014	1	0	1	1	0	1
Argentina	ARG	2014	1	7	8	3	410	413
Armenia	ARM	2014	0	3	3	0	186	186
Australia	AUS	2014	1	10	11	53	2189	2242
Azerbaijan	AZE	2014	0	1	1	0	3	3
Belgium	BEL	2014	5	0	5	55	0	55
Bolivia, Plurinational State of	BOL	2014	0	4	4	0	46	46
Botswana	BOT	2014	0	2	2	0	110	110
Brazil	BRA	2014	3	12	15	241	855	1096
Bulgaria	BGR	2014	17	6	23	1244	246	1490
Canada	CAN	2014	5	16	21	90	444	534
Chile	CHL	2014	3	19	22	138	2665	2803
China	CHN	2014	38	0	38	8597	0	8597
Colombia	COL	2014	0	2	2	0	10	10
Cyprus	CY	2014	1	0	1	1	0	1
Dominican Republic	DOM	2014	0	1	1	0	48	48
Ecuador	ECU	2014	0	2	2	0	13	13
Finland	FIN	2014	7	0	7	447	0	447
France	FRA	2014	1	0	1	7	0	7
Georgia	GEO	2014	3	3	6	29	187	216
Germany	DEU	2014	7	1	8	718	51	769
Hong Kong, China	HKG	2014	3	1	4	13	3	16
India	IND	2014	11	1	12	1055	14	1069
Indonesia	IDN	2014	1	8	9	11	714	725
Iran, Islamic Republic of	IRN	2014	0	1	1	0	179	179
Japan	JPN	2014	12	0	12	2414	0	2414
Kazakhstan	KAZ	2014	2	3	5	17	658	675
Korea, Democratic People's Republic of	KP	2014	1	1	2	11	30	41

Korea, Republic of	KOR	2014	11	3	14	841	16	857
Lao People's Democratic Republic	LAO	2014	0	3	3	0	263	263
Macedonia, North	MKD	2014	0	1	1	0	42	42
Malaysia	MYS	2014	4	2	6	11	39	50
Mauritania	MRT	2014	0	1	1	0	152	152
Mexico	MEX	2014	5	4	9	313	659	972
Mongolia	MNG	2014	0	2	2	0	1379	1379
Morocco	MAR	2014	0	7	7	0	85	85
Namibia	NAM	2014	3	0	3	176	0	176
Netherlands	NLD	2014	3	2	5	23	91	114
Norway	NOR	2014	1	0	1	21	0	21
Oman	OMN	2014	2	4	6	58	183	241
Pakistan	PAK	2014	0	1	1	0	4	4
Peru	PER	2014	5	24	29	23	3896	3919
Philippines	PHL	2014	7	5	12	223	356	579
Poland	POL	2014	3	2	5	137	28	165
Portugal	PRT	2014	0	9	9	0	325	325
Romania	ROU	2014	0	2	2	0	47	47
Russian Federation	RUS	2014	1	3	4	230	19	249
Saudi Arabia	SAU	2014	0	4	4	0	43	43
Serbia	SRB	2014	1	2	3	13	12	25
Singapor	SGP	2014	2	1	3	14	3	17
South Africa	ZAF	2014	2	7	9	75	283	358
Spain	ESP	2014	11	2	13	558	658	1216
Sweden	SWE	2014	9	0	9	254	0	254
Switzerland	CHE	2014	4	0	4	108	0	108
Taipei, Chinese	TWN	2014	10	3	13	171	5	176
Tajikistan	TJK	2014	0	1	1	0	6	6
Tanzania, United Republic of	TZA	2014	0	4	4	0	5	5
Thailand	THA	2014	7	0	7	13	0	13
Türkiye	TUR	2014	0	7	7	0	342	342
United Arab Emirates	ARE	2014	1	0	1	7	0	7
United States of America	USA	2014	2	8	10	37	473	510
Uzbekistan	UZB	2014	2	0	2	52	0	52

Viet Nam	VNM	2014	3	1	4	5	1	6
Zambia	ZMB	2014	0	3	3	0	32	32
Albania	ALB	2015	0	1	1	0	13	13
Argentina	ARG	2015	0	4	4	0	253	253
Armenia	ARM	2015	0	7	7	0	309	309
Australia	AUS	2015	1	10	11	1	1942	1943
Azerbaijan	AZE	2015	0	1	1	0	4	4
Belgium	BEL	2015	5	1	6	13	20	33
Bolivia, Plurinational State of	BOL	2015	0	5	5	0	40	40
Botswana	BOT	2015	0	2	2	0	47	47
Brazil	BRA	2015	3	13	16	496	1083	1579
Bulgaria	BGR	2015	16	5	21	1337	391	1728
Canada	CAN	2015	7	15	22	96	482	578
Chile	CHL	2015	1	23	24	78	9368	9446
China	CHN	2015	41	2	43	13601	14	13615
Colombia	COL	2015	0	1	1	0	19	19
Congo, Democratic Republic of the	COD	2015	0	3	3	0	360	360
Dominica	DM	2015	1	0	1	5	0	5
Dominican Republic	DOM	2015	1	1	2	10	34	44
Ecuador	ECU	2015	0	1	1	0	1	1
Finland	FIN	2015	9	0	9	357	0	357
Georgia	GEO	2015	7	5	12	94	177	271
Germany	DEU	2015	9	1	10	1032	43	1075
Hong Kong, China	HKG	2015	4	1	5	20	15	35
India	IND	2015	7	0	7	2308	0	2308
Indonesia	IDN	2015	1	7	8	10	1712	1722
Iran, Islamic Republic of	IRN	2015	0	1	1	0	286	286
Japan	JPN	2015	11	0	11	4028	0	4028
Kazakhstan	KAZ	2015	2	4	6	12	382	394
Korea, Democratic People's Republic of	KP	2015	1	1	2	12	34	46
Korea, Republic of	KOR	2015	12	2	14	1626	70	1696

Lao People's Democratic Republic	LAO	2015	0	2	2	0	351	351
Macedonia, North	MKD	2015	0	1	1	0	47	47
Malaysia	MYS	2015	3	2	5	32	72	104
Mauritania	MRT	2015	0	1	1	0	245	245
Mexico	MEX	2015	4	12	16	359	811	1170
Mongolia	MNG	2015	0	3	3	0	2280	2280
Montenegro	MNE	2015	1	0	1	1	0	1
Morocco	MAR	2015	0	6	6	0	123	123
Namibia	NAM	2015	2	0	2	200	0	200
Netherlands	NLD	2015	4	5	9	36	99	135
Oman	OMN	2015	3	1	4	72	124	196
Pakistan	PAK	2015	0	1	1	0	6	6
Peru	PER	2015	5	24	29	33	5057	5090
Philippines	PHL	2015	8	3	11	377	339	716
Poland	POL	2015	4	0	4	171	0	171
Portugal	PRT	2015	0	9	9	0	358	358
Romania	ROU	2015	2	3	5	60	51	111
Russian Federation	RUS	2015	2	6	8	122	46	168
Saudi Arabia	SAU	2015	0	2	2	0	53	53
Serbia	SRB	2015	3	1	4	57	1	58
Singapor	SGP	2015	1	1	2	45	2	47
South Africa	ZAF	2015	2	4	6	20	194	214
Spain	ESP	2015	12	4	16	839	826	1665
Sweden	SWE	2015	7	0	7	317	0	317
Switzerland	CHE	2015	5	0	5	253	0	253
Taipei, Chinese	TWN	2015	8	1	9	370	2	372
Tajikistan	TJK	2015	0	1	1	0	8	8
Tanzania, United Republic of	TZA	2015	0	2	2	0	2	2
Thailand	THA	2015	5	0	5	27	0	27
Türkiye	TUR	2015	1	6	7	5	294	299
United Arab Emirates	ARE	2015	1	0	1	1	0	1
United States of America	USA	2015	2	7	9	31	405	436
Uzbekistan	UZB	2015	1	0	1	3	0	3
Viet Nam	VNM	2015	2	1	3	3	4	7
Zambia	ZMB	2015	2	3	5	359	30	389

Argentina	ARG	2016	0	7	7	0	328	328
Armenia	ARM	2016	0	5	5	0	402	402
Australia	AUS	2016	3	9	12	57	1877	1934
Azerbaijan	AZE	2016	0	1	1	0	12	12
Belgium	BEL	2016	11	4	15	84	58	142
Bolivia, Plurinational State of	BOL	2016	0	6	6	0	31	31
Brazil	BRA	2016	2	15	17	596	1156	1752
Bulgaria	BGR	2016	16	4	20	1143	382	1525
Canada	CAN	2016	5	14	19	51	484	535
Chile	CHL	2016	1	24	25	119	10324	10443
China	CHN	2016	39	2	41	16652	5	16657
Colombia	COL	2016	0	2	2	0	39	39
Congo, Democratic Republic of the	COD	2016	0	4	4	0	562	562
Dominican Republic	DOM	2016	0	2	2	0	47	47
Ecuador	ECU	2016	0	3	3	0	7	7
Finland	FIN	2016	7	2	9	404	19	423
France	FRA	2016	1	0	1	9	0	9
Georgia	GEO	2016	5	5	10	148	282	430
Germany	DEU	2016	12	1	13	870	41	911
Hong Kong, China	HKG	2016	4	1	5	24	8	32
India	IND	2016	9	1	10	2248	34	2282
Indonesia	IDN	2016	0	6	6	0	1913	1913
Iran, Islamic Republic of	IRN	2016	0	2	2	0	608	608
Japan	JPN	2016	11	0	11	4555	0	4555
Kazakhstan	KAZ	2016	2	4	6	16	577	593
Korea, Democratic People's Republic of	KP	2016	0	1	1	0	52	52
Korea, Republic of	KOR	2016	13	2	15	1626	39	1665
Macedonia, North	MKD	2016	0	1	1	0	48	48
Malaysia	MYS	2016	4	3	7	184	75	259
Mauritania	MRT	2016	0	1	1	0	193	193
Mexico	MEX	2016	3	14	17	289	1331	1620
Mongolia	MNG	2016	0	1	1	0	1562	1562

Montenegro	MNE	2016	1	0	1	2	0	2
Morocco	MAR	2016	0	8	8	0	113	113
Mozambique	MOZ	2016	1	0	1	72	0	72
Myanmar	MMR	2016	0	1	1	0	2	2
Namibia	NAM	2016	2	0	2	124	0	124
Netherlands	NLD	2016	2	1	3	14	12	26
Oman	OMN	2016	2	2	4	46	101	147
Panama	PAN	2016	1	0	1	6	0	6
Peru	PER	2016	6	25	31	25	7617	7642
Philippines	PHL	2016	9	3	12	741	265	1006
Poland	POL	2016	4	4	8	166	76	242
Portugal	PRT	2016	0	9	9	0	323	323
Romania	ROU	2016	5	2	7	72	42	114
Russian Federation	RUS	2016	1	3	4	227	14	241
Saudi Arabia	SAU	2016	0	4	4	0	81	81
Serbia	SRB	2016	0	1	1	0	2	2
Singapor	SGP	2016	2	2	4	24	4	28
South Africa	ZAF	2016	1	4	5	14	129	143
Spain	ESP	2016	14	4	18	1042	695	1737
Sweden	SWE	2016	8	0	8	294	0	294
Switzerland	CHE	2016	5	0	5	97	0	97
Taipei, Chinese	TWN	2016	10	2	12	436	605	1041
Tajikistan	TJK	2016	0	1	1	0	11	11
Tanzania, United Republic of	TZA	2016	2	0	2	5	0	5
Thailand	THA	2016	4	0	4	80	0	80
Türkiye	TUR	2016	0	6	6	0	244	244
United Arab Emirates	ARE	2016	1	0	1	1	0	1
United Kingdom	GBR	2016	1	0	1	1	0	1
United States of America	USA	2016	2	6	8	42	345	387
Uzbekistan	UZB	2016	1	0	1	6	0	6
Viet Nam	VNM	2016	4	0	4	31	0	31
Zambia	ZMB	2016	1	3	4	544	10	554
Argentina	ARG	2017	0	5	5	0	154	154
Armenia	ARM	2017	0	5	5	0	476	476
Australia	AUS	2017	2	8	10	36	1798	1834
Azerbaijan	AZE	2017	0	1	1	0	12	12
Belgium	BEL	2017	6	2	8	42	44	86

Bolivia, Plurinational State of	BOL	2017	0	4	4	0	26	26
Botswana	BOT	2017	0	1	1	0	5	5
Brazil	BRA	2017	2	14	16	569	1247	1816
Bulgaria	BGR	2017	13	3	16	1727	345	2072
Cambodia	KHM	2017	1	0	1	1	0	1
Canada	CAN	2017	6	12	18	67	398	465
Chile	CHL	2017	2	22	24	89	10818	10907
China	CHN	2017	42	0	42	18559	0	18559
Colombia	COL	2017	0	5	5	0	51	51
Congo, Democratic Republic of the	COD	2017	0	4	4	0	659	659
Dominican Republic	DOM	2017	0	2	2	0	45	45
Ecuador	ECU	2017	0	3	3	0	23	23
Finland	FIN	2017	7	2	9	375	94	469
France	FRA	2017	1	2	3	10	4	14
Georgia	GEO	2017	4	6	10	141	350	491
Germany	DEU	2017	12	1	13	1077	47	1124
Hong Kong, China	HKG	2017	4	1	5	32	2	34
India	IND	2017	9	1	10	2343	46	2389
Indonesia	IDN	2017	0	5	5	0	1539	1539
Iran, Islamic Republic of	IRN	2017	0	3	3	0	1523	1523
Japan	JPN	2017	12	0	12	3827	0	3827
Kazakhstan	KAZ	2017	2	3	5	21	1048	1069
Korea, Democratic People's Republic of	KP	2017	0	1	1	0	1	1
Korea, Republic of	KOR	2017	16	2	18	1951	78	2029
Lao People's Democratic Republic	LAO	2017	0	2	2	0	598	598
Malaysia	MYS	2017	4	3	7	207	254	461
Mauritania	MRT	2017	0	1	1	0	142	142
Mexico	MEX	2017	4	14	18	206	1483	1689
Mongolia	MNG	2017	0	1	1	0	1447	1447
Montenegro	MNE	2017	1	0	1	3	0	3
Morocco	MAR	2017	0	9	9	0	167	167



Mozambique	MOZ	2017	1	0	1	207	0	207
Myanmar	MMR	2017	0	1	1	0	2	2
Namibia	NAM	2017	3	0	3	250	0	250
Netherlands	NLD	2017	1	0	1	11	0	11
Norway	NOR	2017	1	0	1	5	0	5
Oman	OMN	2017	2	1	3	19	28	47
Pakistan	PAK	2017	0	1	1	0	1	1
Peru	PER	2017	4	25	29	131	8025	8156
Philippines	PHL	2017	8	4	12	956	149	1105
Poland	POL	2017	4	2	6	167	18	185
Portugal	PRT	2017	0	9	9	0	271	271
Romania	ROU	2017	3	5	8	68	39	107
Russian Federation	RUS	2017	3	2	5	321	16	337
Saudi Arabia	SAU	2017	0	3	3	0	107	107
Serbia	SRB	2017	1	1	2	4	3	7
Seychelles	SYC	2017	1	0	1	5	0	5
Singapor	SGP	2017	6	1	7	142	3	145
South Africa	ZAF	2017	1	5	6	27	236	263
Spain	ESP	2017	13	5	18	1184	1162	2346
Sweden	SWE	2017	7	0	7	225	0	225
Switzerland	CHE	2017	4	0	4	78	0	78
Taipei, Chinese	TWN	2017	8	1	9	252	353	605
Tajikistan	TJK	2017	0	1	1	0	13	13
Thailand	THA	2017	1	0	1	12	0	12
Türkiye	TUR	2017	0	8	8	0	247	247
United States of America	USA	2017	4	5	9	57	254	311
Uzbekistan	UZB	2017	1	0	1	30	0	30
Viet Nam	VNM	2017	2	0	2	22	0	22
Zambia	ZMB	2017	1	2	3	414	19	433
Australia	AUS	2018	0	9	9	0	2080	2080
Azerbaijan	AZE	2018	0	2	2	0	11	11
Belgium	BEL	2018	3	1	4	16	1	17
Bolivia, Plurinational State of	BOL	2018	0	3	3	0	15	15
Botswana	BOT	2018	0	2	2	0	7	7
Brazil	BRA	2018	3	17	20	481	1246	1727
Bulgaria	BGR	2018	13	4	17	1609	371	1980
Cambodia	KHM	2018	1	0	1	1	0	1
Canada	CAN	2018	7	13	20	106	391	497
Chile	CHL	2018	3	20	23	35	12138	12173

China	CHN	2018	36	3	39	20325	14	20339
Colombia	COL	2018	0	2	2	0	40	40
Congo, Democratic Republic of the	COD	2018	0	3	3	0	741	741
Dominican Republic	DOM	2018	0	3	3	0	45	45
Ecuador	ECU	2018	0	2	2	0	19	19
Finland	FIN	2018	7	2	9	367	105	472
France	FRA	2018	0	2	2	0	7	7
Georgia	GEO	2018	3	6	9	52	341	393
Germany	DEU	2018	11	1	12	921	51	972
Hong Kong, China	HKG	2018	3	1	4	49	1	50
India	IND	2018	9	2	11	1529	108	1637
Indonesia	IDN	2018	1	8	9	14	1599	1613
Iran, Islamic Republic of	IRN	2018	0	5	5	0	210	210
Japan	JPN	2018	12	0	12	4378	0	4378
Kazakhstan	KAZ	2018	2	4	6	41	1065	1106
Kenya	KEN	2018	0	1	1	0	1	1
Korea, Republic of	KOR	2018	19	1	20	2003	111	2114
Lao People's Democratic Republic	LAO	2018	0	1	1	0	483	483
Macedonia, North	MKD	2018	0	1	1	0	37	37
Malaysia	MYS	2018	7	6	13	146	185	331
Mauritania	MRT	2018	0	1	1	0	137	137
Mexico	MEX	2018	5	11	16	277	1628	1905
Mongolia	MNG	2018	0	3	3	0	1437	1437
Montenegro	MNE	2018	1	0	1	2	0	2
Morocco	MAR	2018	0	6	6	0	134	134
Mozambique	MOZ	2018	1	0	1	182	0	182
Namibia	NAM	2018	2	0	2	199	0	199
Netherlands	NLD	2018	2	0	2	5	0	5
Nigeria	NGA	2018	0	1	1	0	1	1
Oman	OMN	2018	2	1	3	24	1	25
Peru	PER	2018	5	22	27	132	8256	8388
Philippines	PHL	2018	8	8	16	408	236	644
Poland	POL	2018	4	1	5	127	150	277
Portugal	PRT	2018	0	5	5	0	249	249
Romania	ROU	2018	1	2	3	37	48	85

Russian Federation	RUS	2018	3	3	6	434	76	510
Saudi Arabia	SAU	2018	0	4	4	0	279	279
Serbia	SRB	2018	1	1	2	26	2	28
Seychelles	SYC	2018	1	0	1	6	0	6
Singapor	SGP	2018	6	1	7	92	1	93
South Africa	ZAF	2018	1	4	5	1	202	203
Spain	ESP	2018	14	6	20	1278	1521	2799
Sweden	SWE	2018	7	2	9	259	12	271
Switzerland	CHE	2018	4	0	4	24	0	24
Taipei, Chinese	TWN	2018	9	1	10	142	185	327
Tajikistan	TJK	2018	0	1	1	0	38	38
Thailand	THA	2018	2	0	2	4	0	4
Türkiye	TUR	2018	5	6	11	93	121	214
United Arab Emirates	ARE	2018	1	0	1	2	0	2
United Kingdom	GBR	2018	0	1	1	0	2	2
United States of America	USA	2018	2	13	15	76	279	355
Uzbekistan	UZB	2018	1	0	1	10	0	10
Viet Nam	VNM	2018	3	1	4	13	5	18
Zambia	ZMB	2018	1	2	3	507	10	517
Australia	AUS	2019	1	10	11	46	1943	1989
Azerbaijan	AZE	2019	0	2	2	0	14	14
Belgium	BEL	2019	3	1	4	28	1	29
Bolivia, Plurinational State of	BOL	2019	0	4	4	0	9	9
Brazil	BRA	2019	3	15	18	403	1129	1532
Bulgaria	BGR	2019	11	3	14	1025	398	1423
Cambodia	KHM	2019	5	0	5	5	0	5
Canada	CAN	2019	6	14	20	133	412	545
Chile	CHL	2019	2	24	26	7	13103	13110
China	CHN	2019	35	1	36	21931	1	21932
Colombia	COL	2019	0	1	1	0	30	30
Congo, Democratic Republic of the	COD	2019	0	3	3	0	688	688
Dominican Republic	DOM	2019	0	2	2	0	27	27
Ecuador	ECU	2019	0	2	2	0	21	21

Finland	FIN	2019	6	0	6	355	0	355
France	FRA	2019	0	2	2	0	5	5
Georgia	GEO	2019	4	6	10	176	373	549
Germany	DEU	2019	11	1	12	913	46	959
Hong Kong, China	HKG	2019	1	0	1	2	0	2
India	IND	2019	8	4	12	1088	287	1375
Indonesia	IDN	2019	1	8	9	2	677	679
Iran, Islamic Republic of	IRN	2019	0	2	2	0	271	271
Japan	JPN	2019	12	0	12	3832	0	3832
Kazakhstan	KAZ	2019	1	3	4	8	1073	1081
Korea, Democratic People's Republic of	KP	2019	1	0	1	2	0	2
Korea, Republic of	KOR	2019	19	2	21	2105	184	2289
Lao People's Democratic Republic	LAO	2019	0	1	1	0	321	321
Macedonia, North	MKD	2019	0	1	1	0	35	35
Madagascar	MDG	2019	0	1	1	0	1	1
Malaysia	MYS	2019	11	4	15	249	164	413
Mauritania	MRT	2019	0	1	1	0	136	136
Mexico	MEX	2019	5	6	11	400	1839	2239
Mongolia	MNG	2019	0	1	1	0	1404	1404
Montenegro	MNE	2019	2	0	2	2	0	2
Morocco	MAR	2019	0	6	6	0	117	117
Mozambique	MOZ	2019	1	0	1	194	0	194
Namibia	NAM	2019	4	0	4	218	0	218
Netherlands	NLD	2019	1	1	2	1	1	2
Nigeria	NGA	2019	0	1	1	0	1	1
Pakistan	PAK	2019	0	1	1	0	1	1
Panama	PAN	2019	0	7	7	0	641	641
Peru	PER	2019	6	26	32	194	8261	8455
Philippines	PHL	2019	8	5	13	481	211	692
Poland	POL	2019	2	0	2	124	0	124
Portugal	PRT	2019	0	6	6	0	185	185
Romania	ROU	2019	2	1	3	102	55	157
Russian Federation	RUS	2019	4	3	7	437	117	554
Saudi Arabia	SAU	2019	1	5	6	2	266	268
Serbia	SRB	2019	4	1	5	125	1	126

Singapor	SGP	2019	1	1	2	3	1	4
South Africa	ZAF	2019	1	6	7	13	247	260
Spain	ESP	2019	11	4	15	735	1031	1766
Sweden	SWE	2019	8	1	9	211	29	240
Switzerland	CHE	2019	3	0	3	21	0	21
Taipei, Chinese	TWN	2019	9	2	11	430	396	826
Tajikistan	TJK	2019	0	1	1	0	10	10
Türkiye	TUR	2019	1	7	8	9	187	196
United Arab Emirates	ARE	2019	0	1	1	0	2	2
United States of America	USA	2019	4	14	18	138	371	509
Uzbekistan	UZB	2019	4	0	4	118	0	118
Viet Nam	VNM	2019	2	0	2	28	0	28
Zambia	ZMB	2019	1	1	2	434	7	441
Albania	ALB	2020	0	1	1	0	15	15
Australia	AUS	2020	2	10	12	41	1299	1340
Azerbaijan	AZE	2020	0	2	2	0	17	17
Belgium	BEL	2020	0	1	1	0	1	1
Bolivia, Plurinational State of	BOL	2020	0	3	3	0	8	8
Botswana	BOT	2020	0	1	1	0	3	3
Brazil	BRA	2020	3	17	20	344	1146	1490
Bulgaria	BGR	2020	13	3	16	735	381	1116
Cambodia	KHM	2020	3	0	3	7	0	7
Canada	CAN	2020	4	15	19	108	445	553
Chile	CHL	2020	3	19	22	30	12754	12784
China	CHN	2020	42	1	43	20814	1	20815
Colombia	COL	2020	0	1	1	0	40	40
Congo	COG	2020	0	1	1	0	3	3
Congo, Democratic Republic of the	COD	2020	1	4	5	87	503	590
Dominican Republic	DOM	2020	0	2	2	0	15	15
Ecuador	ECU	2020	0	2	2	0	95	95
Finland	FIN	2020	8	1	9	414	63	477
France	FRA	2020	0	2	2	0	5	5
Georgia	GEO	2020	2	5	7	99	432	531
Germany	DEU	2020	12	1	13	974	39	1013

Hong Kong, China	HKG	2020	1	0	1	4	0	4
India	ING	2020	9	2	11	708	76	784
Indonesia	IDN	2020	2	10	12	3	1274	1277
Iran, Islamic Republic of	IRN	2020	0	3	3	0	92	92
Japan	JPN	2020	13	0	13	3897	0	3897
Kazakhstan	KAZ	2020	2	5	7	14	1251	1265
Korea, Democratic People's Republic of	KP	2020	1	0	1	1	0	1
Korea, Republic of	KOR	2020	16	3	19	1984	289	2273
Kyrgyzstan	KGZ	2020	0	1	1	0	12	12
Lao People's Democratic Republic	LAO	2020	1	1	2	1	229	230
Macedonia, North	MKD	2020	0	1	1	0	31	31
Malaysia	MYS	2020	9	3	12	108	145	253
Mauritania	MRT	2020	0	1	1	0	135	135
Mexico	MEX	2020	4	4	8	293	1816	2109
Mongolia	MNG	2020	0	1	1	0	1395	1395
Montenegro	MNE	2020	2	0	2	32	0	32
Morocco	MAR	2020	0	4	4	0	123	123
Mozambique	MOZ	2020	1	0	1	177	0	177
Namibia	NAM	2020	3	0	3	150	0	150
Netherlands	NLD	2020	1	1	2	1	1	2
Pakistan	PAK	2020	0	1	1	0	7	7
Panama	PAN	2020	0	9	9	0	734	734
Peru	PER	2020	4	22	26	144	6151	6295
Philippines	PHL	2020	8	4	12	445	69	514
Poland	POL	2020	2	0	2	137	0	137
Portugal	PRT	2020	0	4	4	0	135	135
Romania	ROU	2020	1	1	2	5	46	51
Russian Federation	RUS	2020	2	3	5	301	298	599
Saudi Arabia	SAU	2020	1	3	4	5	319	324
Serbia	SRB	2020	3	2	5	86	55	141
Singapor	SGP	2020	0	1	1	0	1	1
South Africa	ZAF	2020	2	7	9	10	270	280
Spain	ESP	2020	13	5	18	836	584	1420
Sweden	SWE	2020	8	2	10	255	20	275
Switzerland	CHE	2020	4	0	4	72	0	72

Taipei, Chinese	TWN	2020	10	2	12	253	368	621
Tajikistan	TJK	2020	0	2	2	0	4	4
Tanzania, United Republic of	TZA	2020	0	1	1	0	1	1
Thailand	THA	2020	1	2	3	1	3	4
Türkiye	TUR	2020	1	7	8	32	306	338
United Arab Emirates	ARE	2020	1	1	2	13	5	18
United Kingdom	GBR	2020	1	0	1	4	0	4
United States of America	USA	2020	2	12	14	17	389	406
Uzbekistan	UZB	2020	4	0	4	11	0	11
Viet Nam	VNM	2020	1	1	2	5	37	42
Zambia	ZMB	2020	1	4	5	434	156	590
Anguilla	AIA	2021	1	0	1	9	0	9
Armenia	ARM	2021	0	3	3	0	430	430
Australia	AUS	2021	3	7	10	57	605	662
Azerbaijan	AZE	2021	0	3	3	0	16	16
Belgium	BEL	2021	1	0	1	33	0	33
Bolivia, Plurinational State of	BOL	2021	0	4	4	0	10	10
Botswana	BOT	2021	0	3	3	0	47	47
Brazil	BRA	2021	2	17	19	180	1186	1366
Bulgaria	BGR	2021	15	3	18	832	423	1255
Cambodia	KHM	2021	1	0	1	8	0	8
Canada	CAN	2021	5	13	18	106	417	523
Chile	CHL	2021	3	22	25	18	12862	12880
China	CHN	2021	43	0	43	22984	0	22984
Colombia	COL	2021	0	1	1	0	53	53
Congo	COG	2021	0	1	1	0	1	1
Congo, Democratic Republic of the	COD	2021	1	4	5	4	454	458
Dominican Republic	DOM	2021	1	2	3	1	29	30
Ecuador	ECU	2021	0	4	4	0	224	224
Finland	FIN	2021	9	3	12	477	103	580
France	FRA	2021	0	2	2	0	7	7
Georgia	GEO	2021	6	4	10	198	398	596

Germany	DEU	2021	13	1	14	1013	44	1057
Hong Kong, China	HKG	2021	3	0	3	20	0	20
India	ING	2021	9	3	12	922	43	965
Indonesia	IDN	2021	2	11	13	4	2235	2239
Iran, Islamic Republic of	IRN	2021	0	3	3	0	97	97
Japan	JPN	2021	13	0	13	3608	0	3608
Kazakhstan	KAZ	2021	3	4	7	128	966	1094
Kenya	KEN	2021	0	2	2	0	2	2
Korea, Republic of	KOR	2021	16	2	18	1875	560	2435
Lao People's Democratic Republic	LAO	2021	1	2	3	1	179	180
Macedonia, North	MKD	2021	0	1	1	0	32	32
Malaysia	MYS	2021	8	4	12	231	181	412
Mauritania	MRT	2021	0	1	1	0	119	119
Mexico	MEX	2021	4	3	7	269	1552	1821
Mongolia	MNG	2021	0	1	1	0	1283	1283
Montenegro	MNE	2021	2	0	2	11	0	11
Morocco	MAR	2021	0	4	4	0	130	130
Mozambique	MOZ	2021	1	0	1	33	0	33
Myanmar	MMR	2021	0	1	1	0	2	2
Namibia	NAM	2021	2	0	2	143	0	143
Netherlands	NLD	2021	1	0	1	6	0	6
Nicaragua	NI	2021	0	1	1	0	3	3
Pakistan	PAK	2021	0	1	1	0	25	25
Panama	PAN	2021	0	10	10	0	1239	1239
Peru	PER	2021	4	19	23	69	6631	6700
Philippines	PHL	2021	8	4	12	336	95	431
Poland	POL	2021	5	1	6	225	1	226
Portugal	PRT	2021	0	5	5	0	163	163
Romania	ROU	2021	0	4	4	0	39	39
Russian Federation	RUS	2021	2	5	7	97	622	719
Saudi Arabia	SAU	2021	1	3	4	6	206	212
Serbia	SRB	2021	2	8	10	65	504	569
Singapor	SGP	2021	0	1	1	0	1	1
South Africa	ZAF	2021	3	7	10	16	144	160
Spain	ESP	2021	14	5	19	970	630	1600
Sweden	SWE	2021	9	0	9	358	0	358
Switzerland	CHE	2021	3	0	3	156	0	156

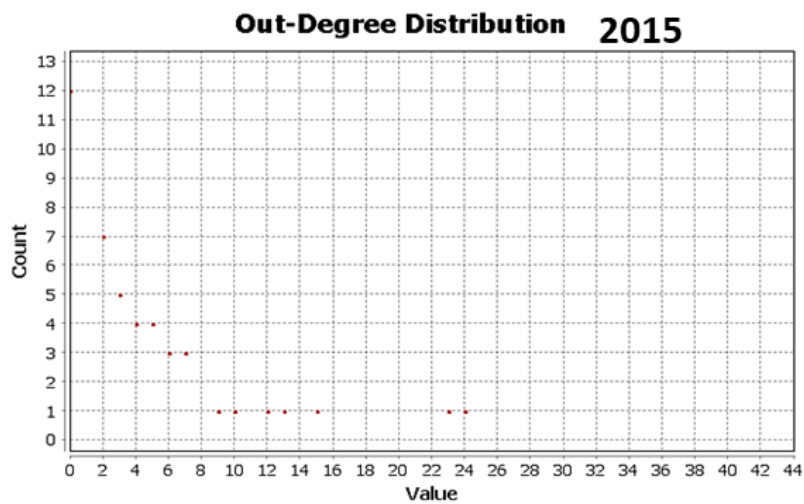
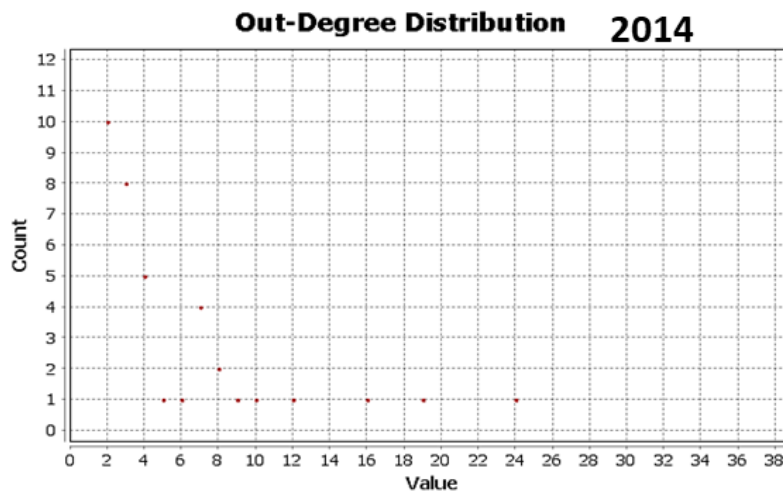
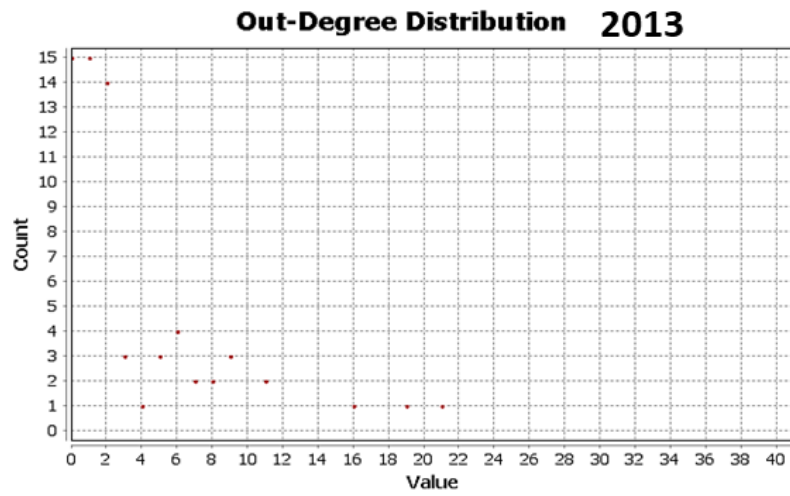


Taipei, Chinese	TWN	2021	8	2	10	315	480	795
Tajikistan	TJK	2021	0	1	1	0	22	22
Tanzania, United Republic of	TZA	2021	1	1	2	1	6	7
Thailand	THA	2021	1	2	3	2	8	10
Türkiye	TUR	2021	2	8	10	12	314	326
United Arab Emirates	ARE	2021	1	1	2	15	6	21
United States of America	USA	2021	1	10	11	11	361	372
Uzbekistan	UZB	2021	3	0	3	49	0	49
Viet Nam	VNM	2021	1	0	1	1	0	1
Zambia	ZMB	2021	1	3	4	312	24	336
Anguilla	AIA	2022	1	0	1	40	0	40
Armenia	ARM	2022	0	6	6	0	411	411
Australia	AUS	2022	0	6	6	0	549	549
Azerbaijan	AZE	2022	0	3	3	0	20	20
Belgium	BEL	2022	1	0	1	20	0	20
Bolivia, Plurinational State of	BOL	2022	0	2	2	0	13	13
Botswana	BOT	2022	0	3	3	0	153	153
Brazil	BRA	2022	3	13	16	110	1048	1158
Bulgaria	BGR	2022	15	5	20	1058	391	1449
Canada	CAN	2022	6	12	18	144	397	541
Chile	CHL	2022	2	17	19	7	11549	11556
China	CHN	2022	36	1	37	24500	1	24501
Congo, Democratic Republic of the	COD	2022	0	7	7	0	922	922
Dominican Republic	DOM	2022	0	1	1	0	29	29
Ecuador	ECU	2022	0	4	4	0	606	606
Finland	FIN	2022	10	0	10	400	0	400
France	FRA	2022	0	2	2	0	9	9
Georgia	GEO	2022	4	4	8	87	416	503
Germany	DEU	2022	12	1	13	842	41	883
Hong Kong, China	HKG	2022	2	0	2	30	0	30
India	IND	2022	9	3	12	1095	30	1125
Indonesia	IDN	2022	3	12	15	4	3134	3138

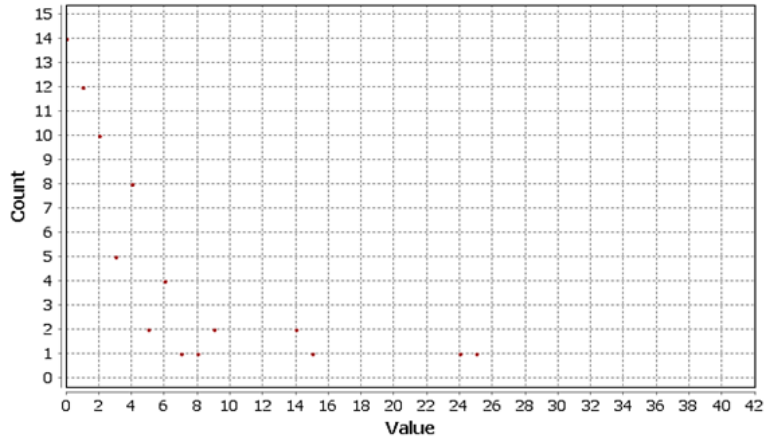
Iran, Islamic Republic of	IRN	2022	1	0	1	3	0	3
Japan	JPN	2022	11	0	11	3653	0	3653
Kazakhstan	KAZ	2022	1	4	5	95	1434	1529
Kenya	KEN	2022	0	1	1	0	7	7
Korea, Republic of	KOR	2022	13	3	16	1982	745	2727
Macedonia, North	MKD	2022	0	1	1	0	37	37
Madagascar	MDG	2022	1	0	1	1	0	1
Malaysia	MYS	2022	8	4	12	311	472	783
Mauritania	MRT	2022	0	1	1	0	67	67
Mexico	MEX	2022	4	4	8	261	1567	1828
Mongolia	MNG	2022	0	1	1	0	1453	1453
Montenegro	MNE	2022	1	0	1	11	0	11
Morocco	MAR	2022	0	5	5	0	123	123
Namibia	NAM	2022	3	0	3	166	0	166
Netherlands	NLD	2022	3	0	3	8	0	8
Nicaragua	NI	2022	0	1	1	0	3	3
Pakistan	PAK	2022	0	1	1	0	68	68
Panama	PAN	2022	0	10	10	0	1300	1300
Papua New Guinea	PNG	2022	1	0	1	1	0	1
Peru	PER	2022	3	18	21	32	6651	6683
Philippines	PHL	2022	8	3	11	270	90	360
Poland	POL	2022	4	1	5	166	2	168
Portugal	PRT	2022	0	5	5	0	142	142
Romania	ROU	2022	0	2	2	0	46	46
Russian Federation	RUS	2022	3	0	3	75	0	75
Serbia	SRB	2022	0	11	11	0	1191	1191
Singapor	SGP	2022	0	2	2	0	2	2
Singapore	SGP	2022	5	0	5	70	0	70
South Africa	ZAF	2022	1	2	3	2	99	101
Spain	ESP	2022	12	4	16	919	892	1811
Sweden	SWE	2022	7	0	7	251	0	251
Switzerland	CHE	2022	3	0	3	115	0	115
Taipei, Chinese	TWN	2022	8	3	11	358	528	886
Tajikistan	TJK	2022	0	2	2	0	96	96
Tanzania, United Republic of	TZA	2022	0	5	5	0	31	31
Thailand	THA	2022	1	1	2	2	3	5
Türkiye	TUR	2022	4	7	11	23	399	422

United Arab Emirates	ARE	2022	2	0	2	2	0	2
United States of America	USA	2022	2	9	11	22	356	378
Uzbekistan	UZB	2022	2	1	3	160	2	162
Zambia	ZMB	2022	1	3	4	271	42	313

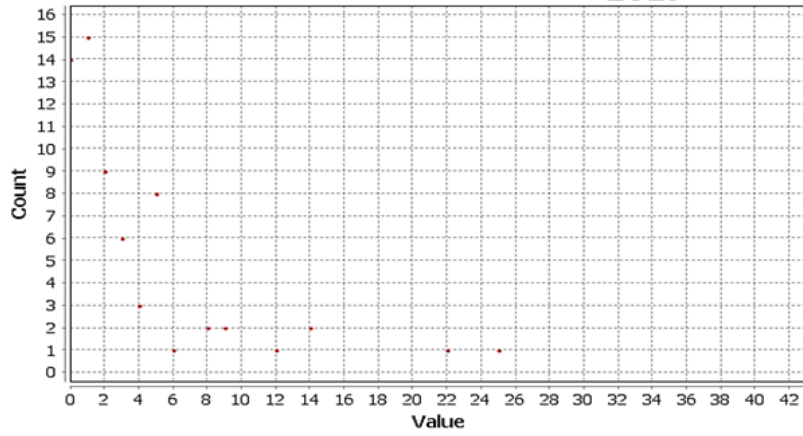
## Appendix 2: Out-Degree Distribution



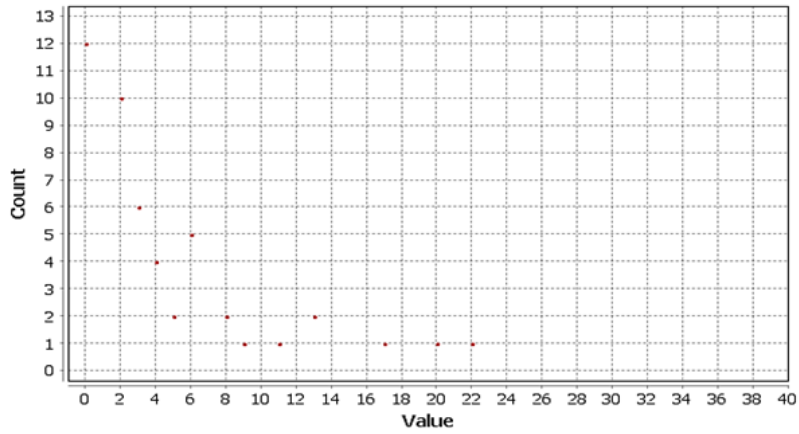
**Out-Degree Distribution 2016**



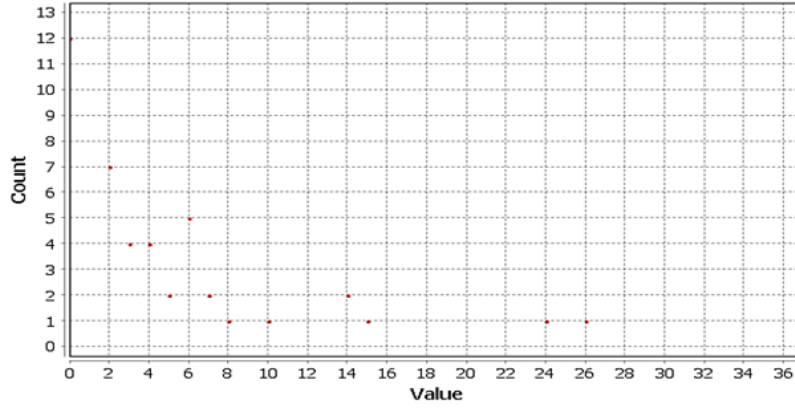
**Out-Degree Distribution 2017**



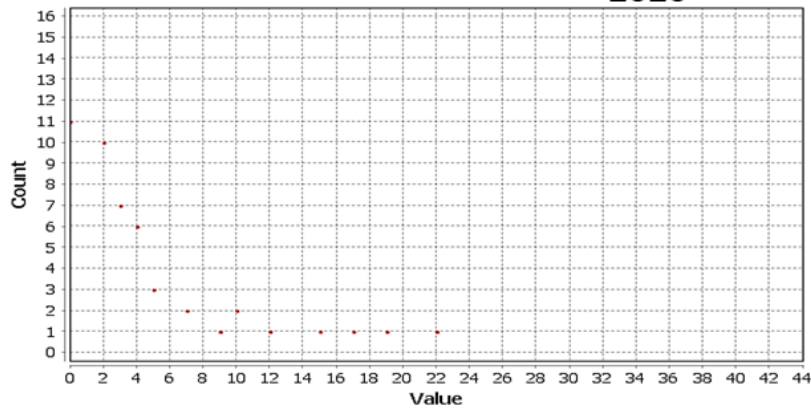
**Out-Degree Distribution 2018**



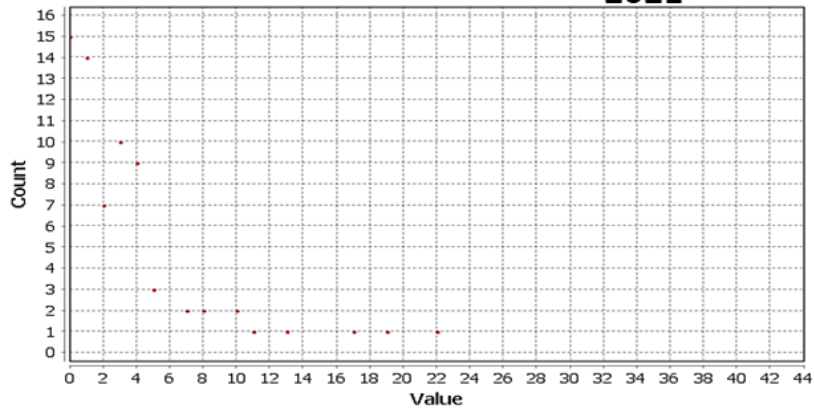
**Out-Degree Distribution 2019**



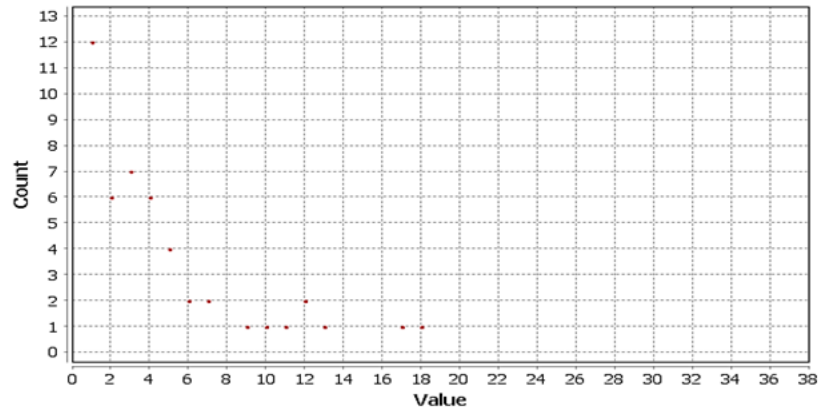
**Out-Degree Distribution 2020**



**Out-Degree Distribution 2021**

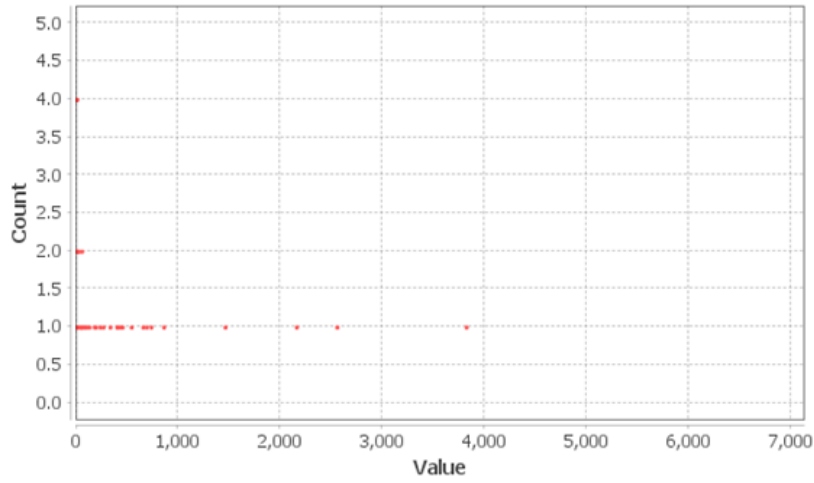


### Out-Degree Distribution 2022

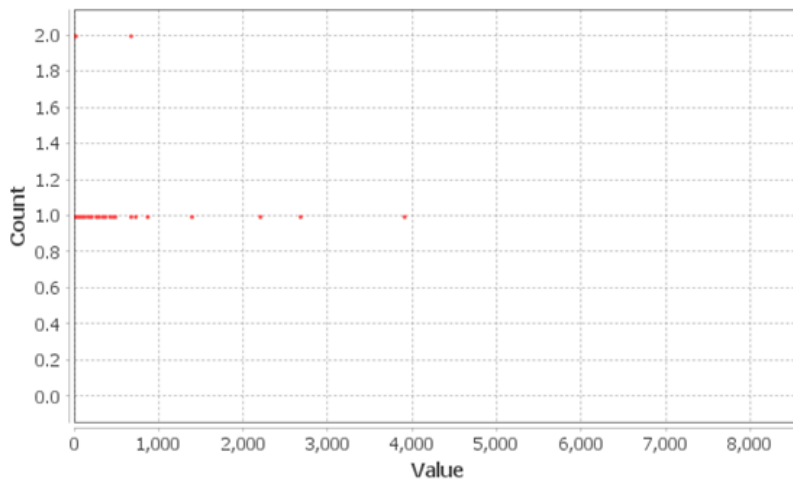


### Appendix 3: Weighted Out-Degree Distribution

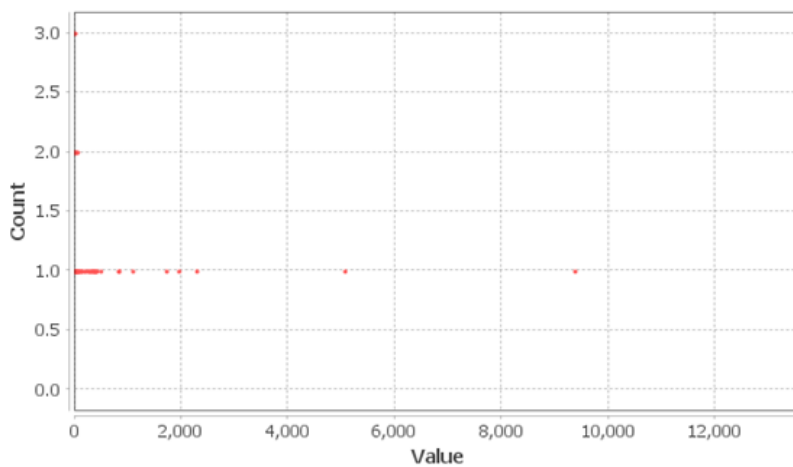
#### Weighted Out-Degree Distribution 2013



#### Weighted Out-Degree Distribution 2014

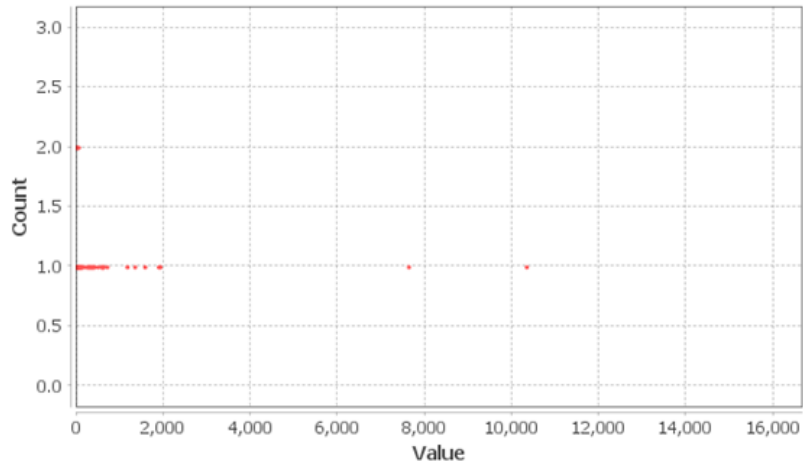


#### Weighted Out-Degree Distribution 2015

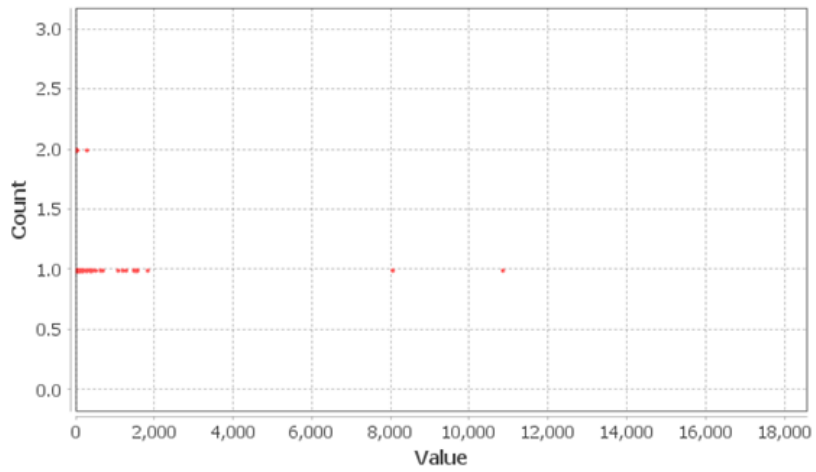




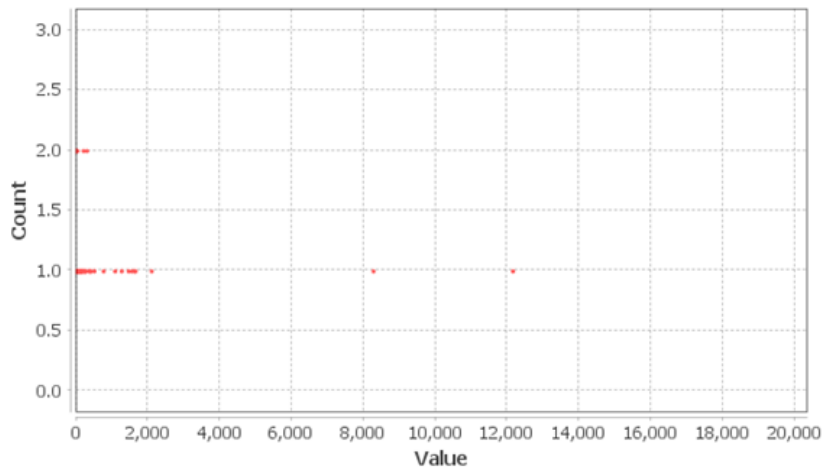
### Weighted Out-Degree Distribution 2016



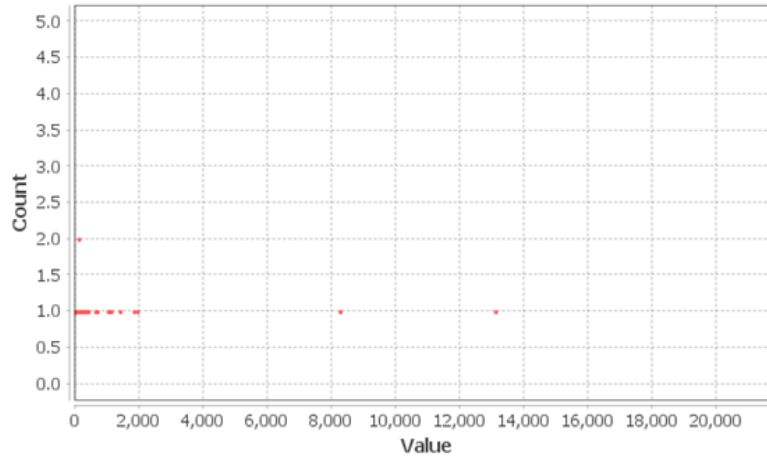
### Weighted Out-Degree Distribution 2017



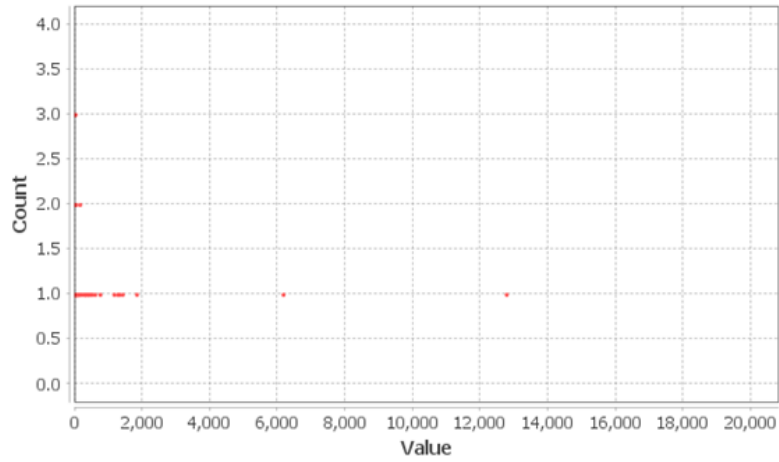
### Weighted Out-Degree Distribution 2018



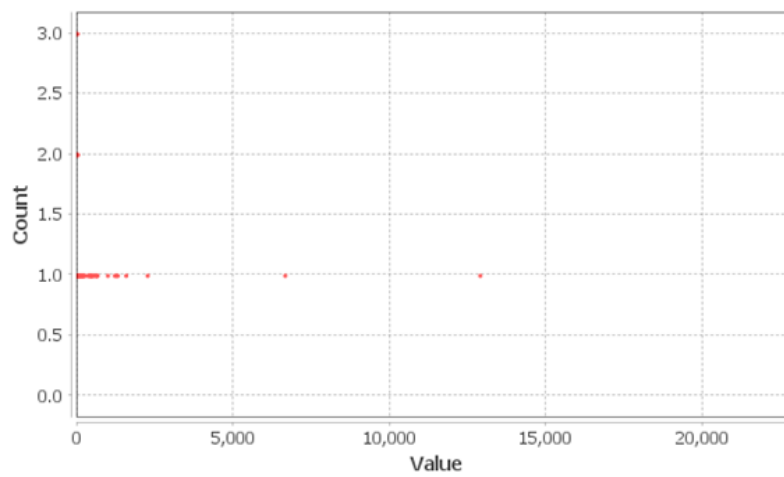
### Weighted Out-Degree Distribution 2019



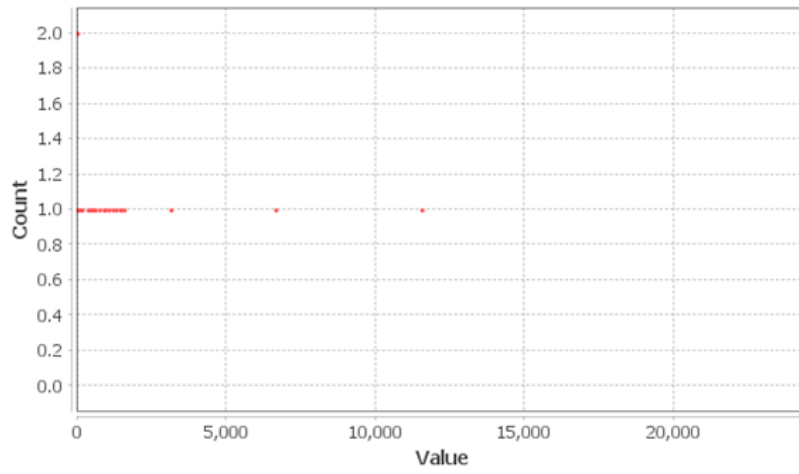
### Weighted Out-Degree Distribution 2020



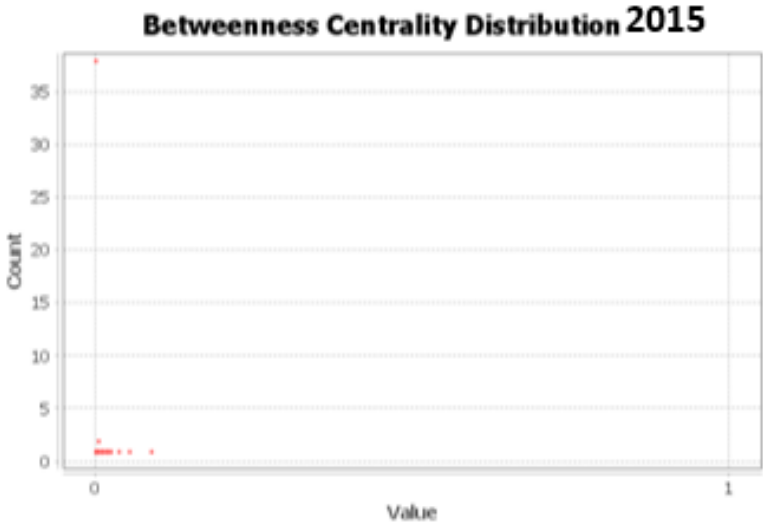
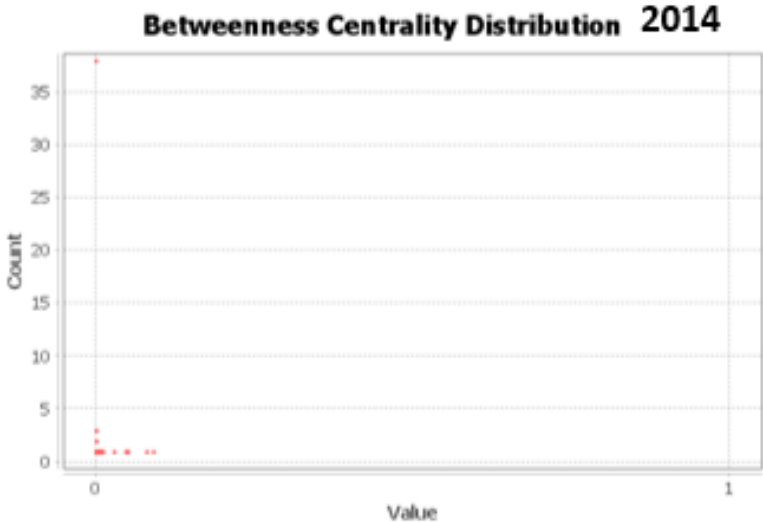
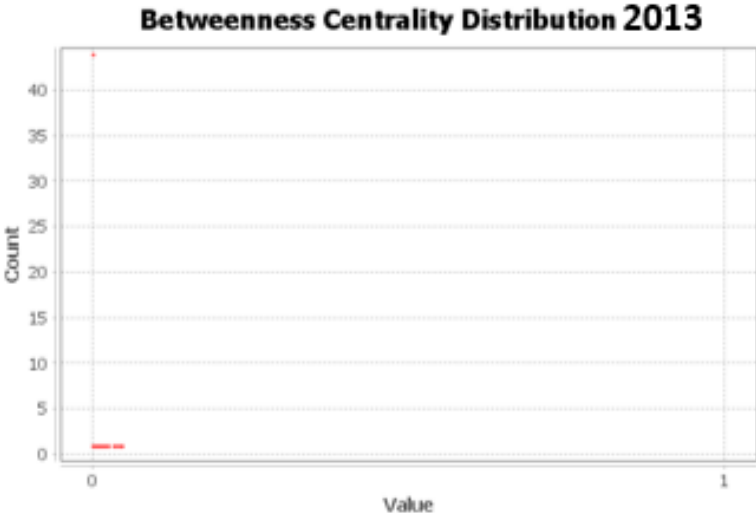
### Weighted Out-Degree Distribution 2021



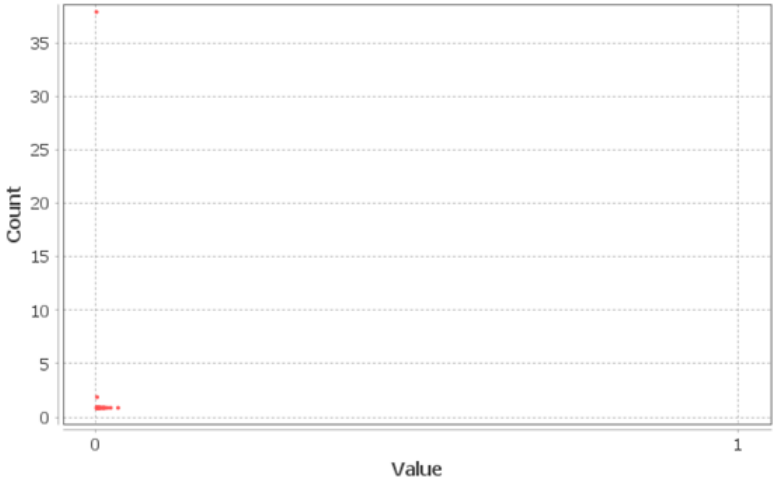
### Weighted Out-Degree Distribution 2022



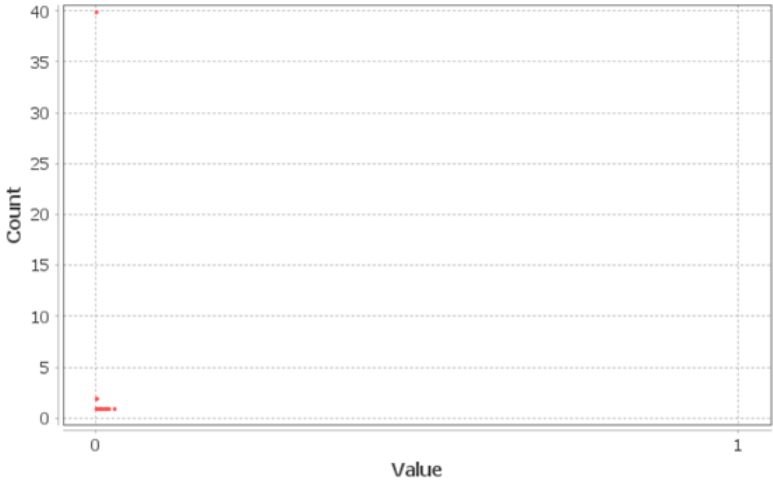
Appendix 4: Betweenness Centrality



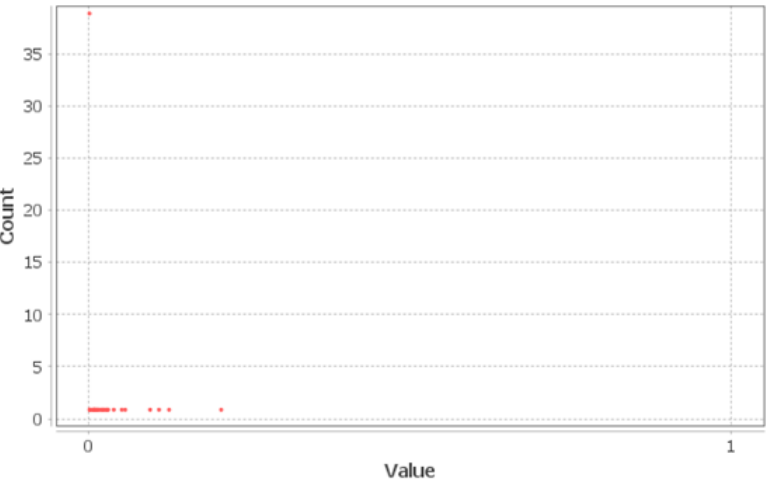
**Betweenness Centrality Distribution 2016**



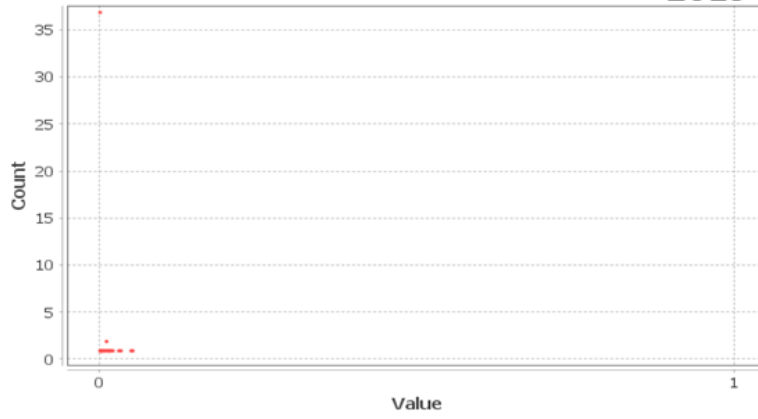
**Betweenness Centrality Distribution 2017**



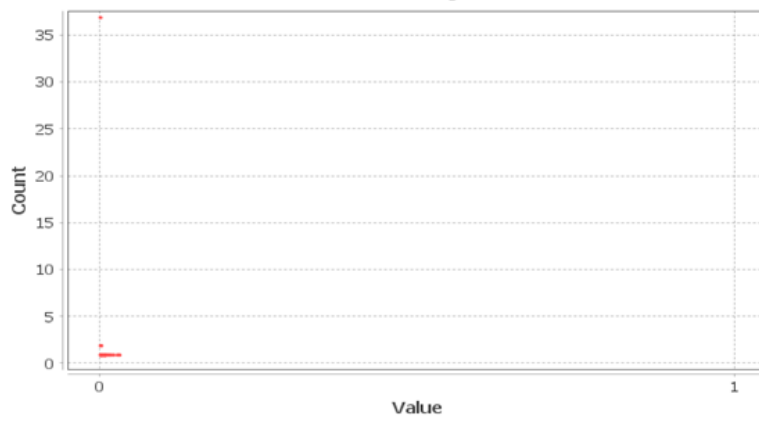
**Betweenness Centrality Distribution 2018**



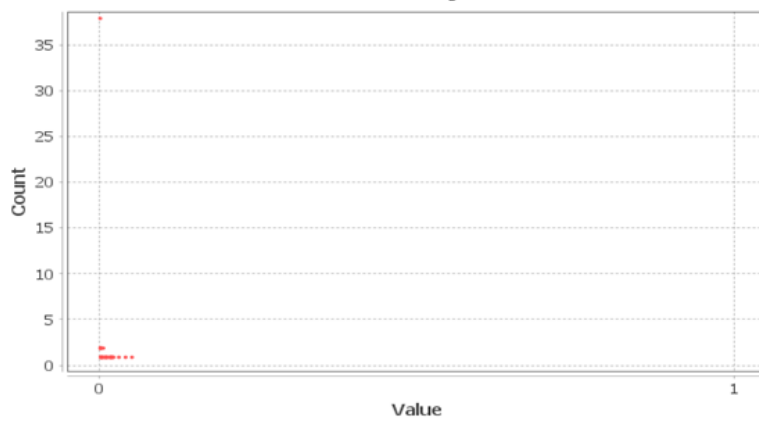
**Betweenness Centrality Distribution 2019**



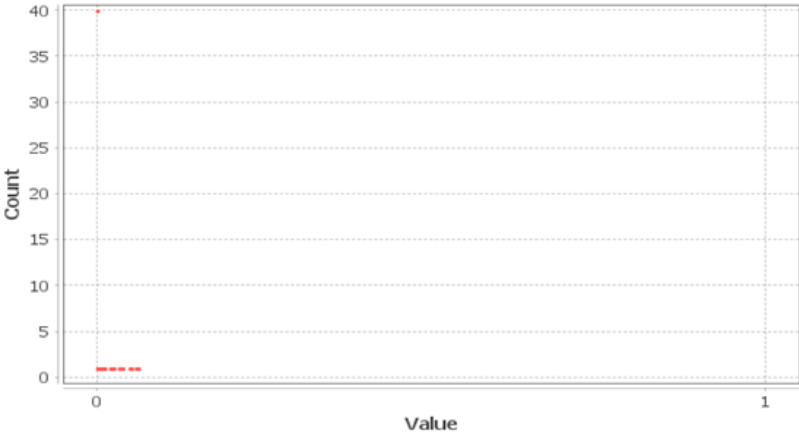
**Betweenness Centrality Distribution 2020**



**Betweenness Centrality Distribution 2021**



### Betweenness Centrality Distribution 2022



# 국문 요약(Abstract in Korean)

## 페루의 글로벌 구리 광석 무역에서 차지하는 위치 역학: 사회 네트워크 분석

마리아 발레리아 아귀나가 폰세카  
협동과정 기술경영·경제·정책전공  
서울대학교 대학원

에너지 전환 시대가 다가올수록 구리는 국제에너지기구(IEA)가 파리협정에서 합의한 목표를 달성하는 데 더욱 더 중요한 역할을 하게 될 광물로 강조한 전략광물이다. 국제에너지기구의 지속가능개발 시나리오에 따르면 구리의 수요는 향후 20년 동안 40% 이상 증가할 것으로 예상된다. 한편 전 세계 구리 광석 생산량의 약 50%가 단 3개국에 집중되어 있으며, 남미 서부지역국가, 특히 칠레와 페루가 전 세계 공급량의 40%를 차지한다.

본 논문에서는 페루가 구리 광석 생산 및 국제무역에서 가지는 중요한 역할을 바탕으로 하여 미래의 수요 증가 및 생산 증대에 따라 변화하고 있는 전세계 구리 광석의 무역 네트워크 내에서 페루가 가지게 될 역동적인 역할을 탐구하고자 한다. 페루의 증대되는 수출에서의 위상을 탐색하고, 구리 광석 수출의 가치와 국제 무역 파트너의 변화를 조사, 분석하며, 2013년에서 2022년 10년 기간 동안의 글로벌 구리 광석 무역 네트워크에 미치는 영향을 평가하고자 한다. 본 연구에서는 소셜 네트워크 분석 방법론을 적용하여 국제 구리 무역에서 가지는 페루의 위상과 전략적 역할의 변화를 분석하였다.

분석 결과 페루와 구리 광석의 무역 파트너들과의 상호 연결성이 증가하고 클러스터링 계수가 증가함에 따라 강화되어 강력하고 직접적인 무역 관계를 나타냄을



확인하였다. 그러나 전세계 무역에서의 구리 광석 공급국으로서의 페루의 새로운 경쟁자, 특히 인도네시아와 브라질의 등장으로 인해 새로운 도전과 필요한 전략적 적응이 필요함도 확인하였다.

이 연구의 결론으로 글로벌 구리 광석 네트워크에서 페루의 역할은 시장 변동과 경쟁 압력에 대한 능숙한 탐색을 그 중요한 특징으로 가지고 있음을 확인한 것이다. 이를 바탕으로 하여 세계 구리 생산업에서 페루의 주요 위치, 에너지 전환에 대한 기여, 전략적 국제 상호 작용에 대한 이해를 심화할 수 있다. 정책적 시사점으로 구리 수출국으로서 탁월한 페루의 지위를 지속적으로 유지하고 높이기 위해서는 다각화, 외교 관계 강화, 위험 완화 전략 실행의 필요성이 큼을 확인하고 있다. 본 연구의 결과 및 정책적 시사점은 정책 입안자, 경제학자 및 업계 이해관계자에게 전세계 구리 광석 무역시장의 역학에 대한 중요한 통찰력을 제공한다 또한 페루의 정책결정에 필요한 기초자료를 제공한다.

**주요어:** 구리, 소셜 네트워크, 페루, 국제 무역

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