Maritime trade and economic development in North Korea

César Ducruet
In Joo Yoon

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EconomiX - UMR 7235 Bâtiment Maurice Allais
Université Paris Nanterre 200, Avenue de la République
92001 Nanterre Cedex

Site Web : economix.fr
Contact : secreteriat@economix.fr
Twitter : @EconomixU

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César DUCRUET

UMR 7235 EconomiX

French National Center for Scientific Research (CNRS)

cesar.ducruet@economix.fr

In Joo YOON

Northern & Polar Regions Research Department

Korea Maritime Institute (KMI)

mouthpiece@kmi.re.kr

Abstract

The North Korean economy is experiencing a deepening economic and political crisis since the early 1990s. Although North Korea is not commonly seen as a shipping nation, its major cities are coastal, and it hosts nine international trading ports. However, little is known about the role of maritime transport in its development. This article uses vessel movement data to reconstitute the maritime network linking North Korean ports and other ports, over the period 1977-2021. Besides the drastic connectivity loss, main results conclude about a limited role of maritime transport in economic development, except for its participation to China's increasing grip on North Korea. This research brings new knowledge about North Korea and contributes to advance maritime network studies in general.

Keywords: *multivariate analysis, international trade, maritime connectivity, network analysis.*

1. Introduction

Maritime connectivity is recognized to be a fundamental determinant of trade (Fugazza and Hoffmann, 2017; Arvis et al., 2019) and economic development (Lane and Pretes, 2020). However, little is known about the case of North Korea in such respect, which followed a socialist development model favoring land versus sea transport. Maritime transport in North Korea is often associated with inter-Korean naval disputes, spying vessels visiting Japanese ports, and more recently, smuggling activities through ship-to-ship

transfers in high seas between North Korean and Chinese vessels for instance (Project Sandstone, 2020). In addition, North Korea is recognized to be a relatively closed country, and its foreign trade is increasingly occurring through the land border with China. Yet the deepening economic and political crisis affects the whole economy and territory, with a growing deterioration of all transport infrastructures (Ducruet and Jo, 2008).

Since the early 1990s, the collapse of the Eastern Block provoked a drastic decline of North Korea's preferential trade relationships, of which Russia and China as major partners. This relative isolation intermingled with internal turmoil, due to the lack of combustibles and capital to maintain agriculture and industry, the difficult presidential leadership transition, and natural disasters, notwithstanding a trade embargo – all of this in less than a decade. Nowadays GDP thus scores below its value in 1990 according to Koen and Beom (2020). Yet, North Korea has been able to conduct international trade in various ways, such as through economic reforms, inter-Korean cooperation, and intensified relationships with China. Additional UN sanctions, however, were imposed in recent years, to avoid the potential risk of nuclear activities.

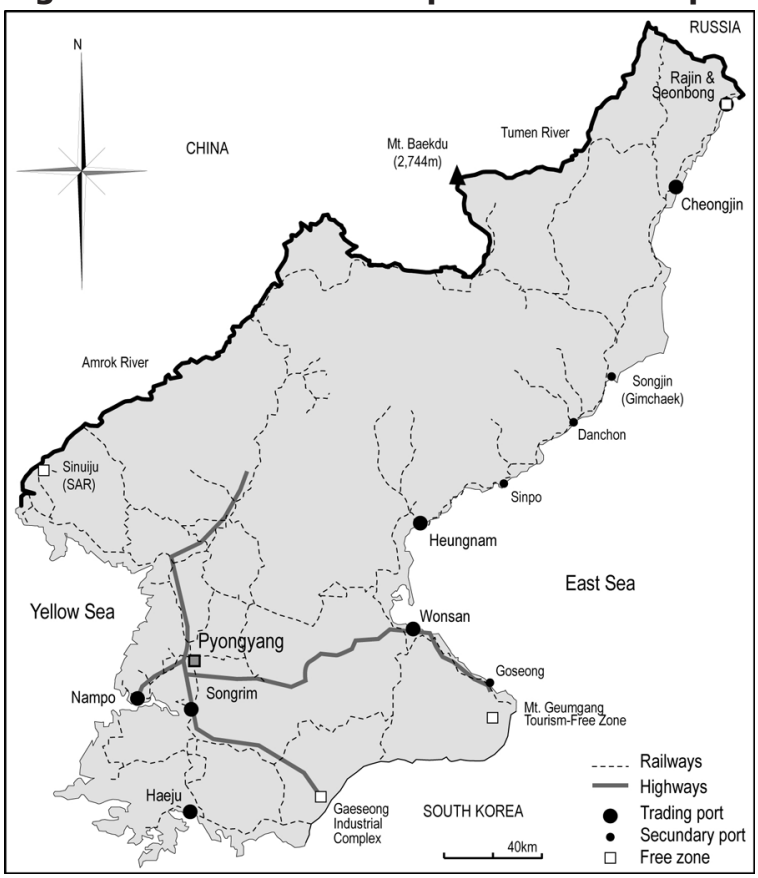
Despite these issues, North Korea possesses nine international trading ports, which locate within or near its major cities (Figure 1). The increasing difficulties of moving freight by road or rail confer to ports a potential advantage for deep-sea and coastal shipping. New port facilities have been developed in the capital region and at the northeastern border with China and Russia in the 2000s, as well as in the late 2010s (Sunchon, Ryongchon-Haeyang) (Son, 2020). In addition, North Korea locates near China, Far East Russia, Japan, and South Korea, which are currently its main trade partners and with which relationships are inevitably maritime[1].

As such, ports and maritime transport in North Korea have been studied from various perspectives. Some authors described the characteristics of the fleet (Smith, 2009) and of transport - of which port - infrastructures (Tsuji, 2005). Others analyzed traffic dynamics in the port system (Ducruet et al., 2009) and inter-port connections with South Korea and China (Ducruet et al., 2017). The present research wishes to complement these works by an analysis of the relationship between maritime connectivity, trade, and economic development. Its main objective is to reveal the nature and

1 Since the end of the Korean War (1953), no peace treaty has been signed. North Korea and South Korea remain separated by the Demilitarized Zone (DMZ).

evolution of this relationship under contrasted political contexts. This research thus innovates by looking at a specific sector of North Korea's economy (maritime transport) and contributes to the literature on maritime networks and international trade with a specific case (North Korea).

Figure 1 – North Korean ports and transport infrastructures



Source: own elaboration

The remainders of the article are organized as follows. Section 2 reviews the rare existing works discussing the relationship between maritime connectivity, trade, and economic development. Data and methodology are introduced in Section 3. Section 4 presents the results in three successive steps, from overall connectivity evolution to dynamic factor analysis. Section 5 explains shipping and economic dynamics along with political factors. We conclude about the contribution of these analyses to existing research in Section 6.

2. Literature review

Maritime network analysis, despite pioneering steps in the late 1960s made by geographers (Robinson, 1968), is a relatively young subfield of both maritime studies and network science (Ducruet, 2020; Artikis and Zissis, 2021). Until recently, most related research remained rather static, while considering the graph (i.e., network) in an abstract space, only based on its topology – the structure of its nodes and links. This was caused by the difficulty accessing relevant data or by the study focus, from management (e.g., competition in liner shipping networks) to operations research (e.g., vessel trajectories and accidentology) and physics (i.e., scale-free and small-world network models). As the maritime network is a spatial (or geographic) network, and is a component of international trade, scholars gradually integrated territorial indicators in their analysis (for an extensive review, see Ducruet, 2020). At the city and regional (subnational) levels, some studies analyzed the correlation between maritime centrality and various socio-economic features such as population, GDP, and employment by economic sector. Other works at the national level were more focused on international trade. For instance, Fugazza and Hoffmann (2017) analyzed the relationship between bilateral maritime liner shipping connectivity and exports in containerizable goods during the period 2006–2013. In particular, they demonstrated the negative effect of lacking a direct maritime connection and of additional transshipment on export value. The study by Kosowska-Stamirowska (2020) concluded that simple motifs (i.e., the number of common neighbors) better predict the creation of new maritime links than more classic attributes commonly used in gravity models of trade (i.e., GDP, population).

Despite the aforementioned advances, much research remains to be done in the field of maritime network analysis. Based on the case of North Korea, our objective is to deepen the understanding of the interplay between maritime network evolution and wider trade, economic, and political evolutions. This approach is parent to earlier studies having provided a long-term, historical analysis of a maritime network in relation to the transition from colonialism to globalization (Tsubota et al., 2017; Castillo and Ducruet, 2017) or from socialism to capitalism (Zreik et al., 2017). However, such studies only looked at the changing spatial distribution of maritime flows, without considering territorial attributes. Our research thus innovates through its cross-analysis of shipping, trade, and economic data to better unravel the interdependencies at stake.

3. Data and methodology

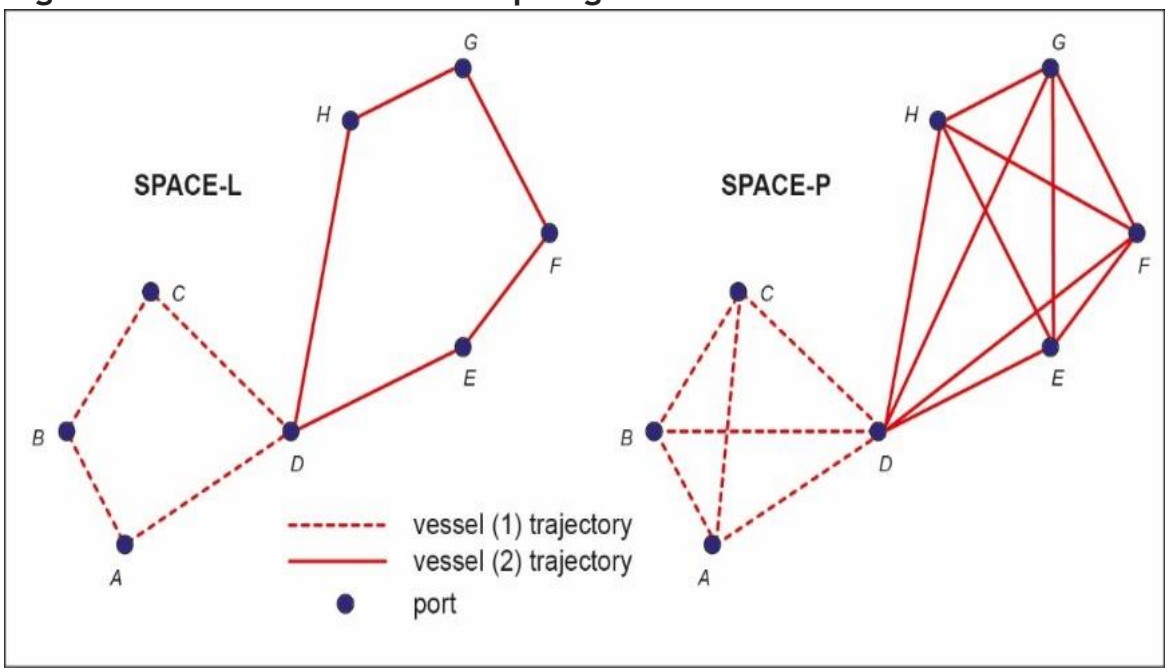
3.1. Maritime network construction

The data used in this study is the maritime traffic passing through North Korean ports. It takes the form of daily vessel movements that have occurred between the 1st of January 1977 and the 18th of April 2021 – nearly 44 years. The choice of the period is dictated by data availability. Data prior to 1977 can only be found in paper format and is difficult to extract massively to reach a sufficient level of representativeness. The ending date corresponds to the date of data ordering towards the provider, namely Lloyd's List Intelligence (Informa Group), a world leader in marine insurance and information. It is estimated that currently, Lloyd's insures (and tracks the vessel movements of) about 80% of the world fleet. As an external source, it allows to palliate the lack and inconsistency of information on North Korean ports, shipping flows, and trade.

The obtained dataset details the dates of arrival and departure at and between ports. It contains the call sequence, for each vessel, for the 10 previous and 10 next ports before and after calling in North Korea. Traffic is defined in this study as the product of vessel capacity and call frequency. Such a method, however, is only a surrogate of actual shipping tonnage, as the data does not indicate how much cargo has been truly carried and handled.

The relational (or network) perspective is based on the construction of an origin-destination matrix considering the space-P topology of the network (Figure 2). This allows the analysis of long-range interactions, as otherwise the port of Nampo in North Korea (i.e., *d* in the figure) would never be considered connected with Rotterdam (i.e., *g*) and Santos (i.e., *b*). The space-P topology thus considers that within a certain amount of time (yearly basis in this research), all ports called by the same vessel are mutually connected, thus creating a complete subgraph. As in Figure 1, the global matrix or network is the combination of all individual subgraphs.

Figure 2 – Maritime network topologies



Source: Hu and Zhu (2009)

3.2. Towards a multivariate analysis

Several maritime and economic variables base the core of the analysis (Table 1). Several indicators can be calculated based on the network, such as degree centrality, the most common index, namely the number of connections of a given port or country. The weighted degree considers vessel size and call frequency on links. As the maritime network is a spatial network, the interaction range can be measured and corresponds for each node to the average kilometric length of its maritime connections.

"Mass" variables are retained, of which total traffic, GDP, and total foreign trade. Total traffic is decomposed by main ship types as well as by main overseas connection. The North Korean fleet is characterized by its average vessel age and average vessel size. The Gini coefficient is applied to the distribution of traffic among North Korean ports, as a measure of internal concentration. Finally, the share of foreign vessel traffic at North Korean ports is calculated.

Our methodology consists in analyzing connectivity through three successive and complementary steps. The first step will describe overall changes of global connectivity, with network indicators and a single linkage analysis (SLA). The method of SLA (Nystuen and Dacey, 1961) is applied to the whole global network for each period of 11 years. It helps revealing the key hubs of the

network, the dominant connections, and the underlying geography of the emerging subsystems or "nodal regions". A second step is a multivariate analysis (factor analysis) of shipping indicators, willing to identify interrelations among them and the influence of the political context. The final step is a multiple regression analysis of North Korean GDP.

Table 1 – List of variables

Total_grt	Total maritime traffic of North Korea (weighted degree)
Total_gdp	Total Gross Domestic Product of North Korea
Total_trade	Total foreign trade of North Korea (including trade with South Korea)
Avg_age	Average age of the North Korean fleet
Avg_size	Average capacity of North Korean vessels (GRT)
Avg_time	Average ship turnaround time at North Korean ports (No. days)
Share_foreign	Share of foreign vessels' traffic in total North Korean port traffic
Gini	Concentration level of the North Korean port system
K_spaceP	Degree centrality of North Korea (nb. Shipping connections)
Km_spaceP	Interaction range of North Korea (avg. kilometric length of shipping connections)
Container, general cargo, liquid bulk, passenger & vehicle, solid bulk	Share of each traffic at North Korean ports
China, Japan, South Korea, Russia, rest of world	Share of each country in total shipping traffic
7 sectors	Share of each sector in total North Korean GDP
Coal, fishery, iron ore, non-ferrous metals, steel, cement	Volume of production (tons)
Import_oil	Volume of crude oil imports (tons)
Nuclear_tests	Year dummy for nuclear tests
Missile_tests	Year dummy for missile launches

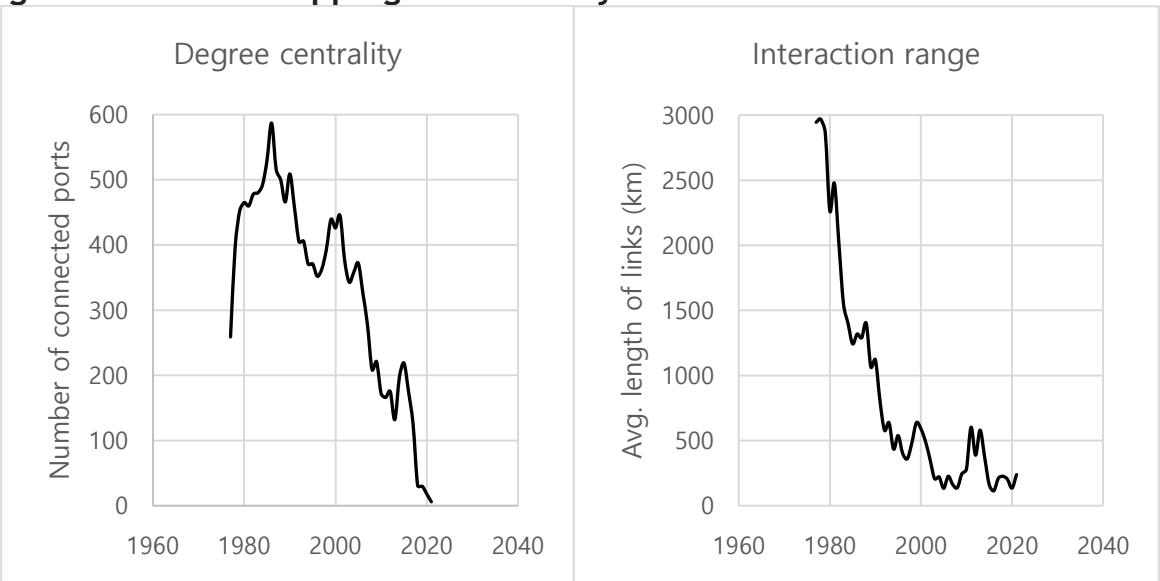
Source: Lloyd's List data, Bank of Korea data

4. Connectivity analysis

A first step into the analysis of maritime connectivity is to compare degree centrality and interaction range over the period (Figure 3). We see that both indicators fell sharply. Degree centrality, however, was growing until 1986, contrary to interaction range. This means that connectivity was still growing before the crisis of the late 1980s/early 1990s, but the geographic depth of maritime connections already faltered. Another difference is interaction range reached lowest values already in the mid-2000s, compared with degree centrality in 2021. One

common point is that the two curves startled between 1999 and 2001, when North Korea received aid from overseas (food, oil, medical supplies). The other exception to the decline lies between 2014-2017 for degree and 2009-2015 for average distance. The decline between 2014-2017 for degree centrality is due to the intensive coal export to selective ports of China. The other decline between 2009-2015 for average distance of interaction range is due to the cease of inter-Korean shipping and the time gap until they find the new trading partner, which is China.

Figure 3 - Global shipping connectivity



Source: own realization based on Lloyd's List data

The single linkage analysis is decomposed into four subperiods (Figure 4). It is important to note that all ports in the figure have been connected to North Korea, directly or indirectly, as part of vessel voyages. The disconnection among the nodal regions is part of the method to reveal distinct subsystems within the globally connected network. One map is placed under each network diagram to represent the same information geographically, together with more indication about the presence and level of North Korean vessel traffic in total overseas port traffic.

4.1. 1977-1987

The first period is characterized by two large components or "nodal regions", respectively centered upon Yokohama and Hong Kong. Due to barrier effects, and notably geographic proximity, a smaller nodal region centered on Nakhodka stands apart, including also Vladivostok and Rajin. The other relatively small nodal region is polarized by Chiba and Himeji (Japan), together with South Korean ports (Yeosu, Busan, Incheon), Qinhuangdao, Kaohsiung, and interestingly Sirri Island in Iran.

The two largest nodal regions carry a lot of information. They are geographically different: the one centered on Hong Kong is an East-West corridor extending from North Korea to the Black Sea and northern Europe through Singapore and the Red Sea (Aden, Jeddah), while Yokohama's nodal region is more turned towards the Asia-Pacific. In the first one, Nampo appears as a crucial hub with direct connections to all continents. It has preferential linkages with Mumbai and Jeddah, which connect primarily Europe; Durban, which acts as an intermediary hub for Africa and Latin America; Constanza, Mina al Ahmadi, New Orleans, Colombo, and Jakarta, the latter two being bound to Asian traffic. Hungnam is directly connected with Singapore but also to Havana (Cuba) and Kharg Island (Iran) and an important number of European ports. Hong Kong and Singapore act as their hubs towards Black Sea, North Sea, and Baltic Sea secondary hubs, as a reflection of trade vitality with the Eastern Block. Such secondary hubs act as "transitive" nodes, i.e. they provide North Korea indirect access to their own trades, as part of a global, interlinked structure. Singapore stands apart given its limited traffic compared with its enormous centrality.

For the other large nodal region centered on Yokohama, Vancouver and Los Angeles are transitive hubs for the Americas, but also Shanghai and Dalian with a diversified connectivity. Yokohama is a powerful internal hub for Japan, and to be noted is the largest inter-port flow link between Wonsan and Niigata, transporting goods but also people through a regular ferry link since the 1970s[2]. During this decade, other logics than

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2 In 1971 a ferry route was opened between Niigata and Wonsan mostly to transport goods and North Korean Japanese known as Chongryon to the fatherland for family visits throughout the 1970s, 80s and 90s. However, this service was halted in 2006 when Japan banned North Korean ships from its waters. Chongryon operated commercial vessels transporting goods between Japan and North Korea with few restrictions or inspections, while also remitting earnings from Koreans in

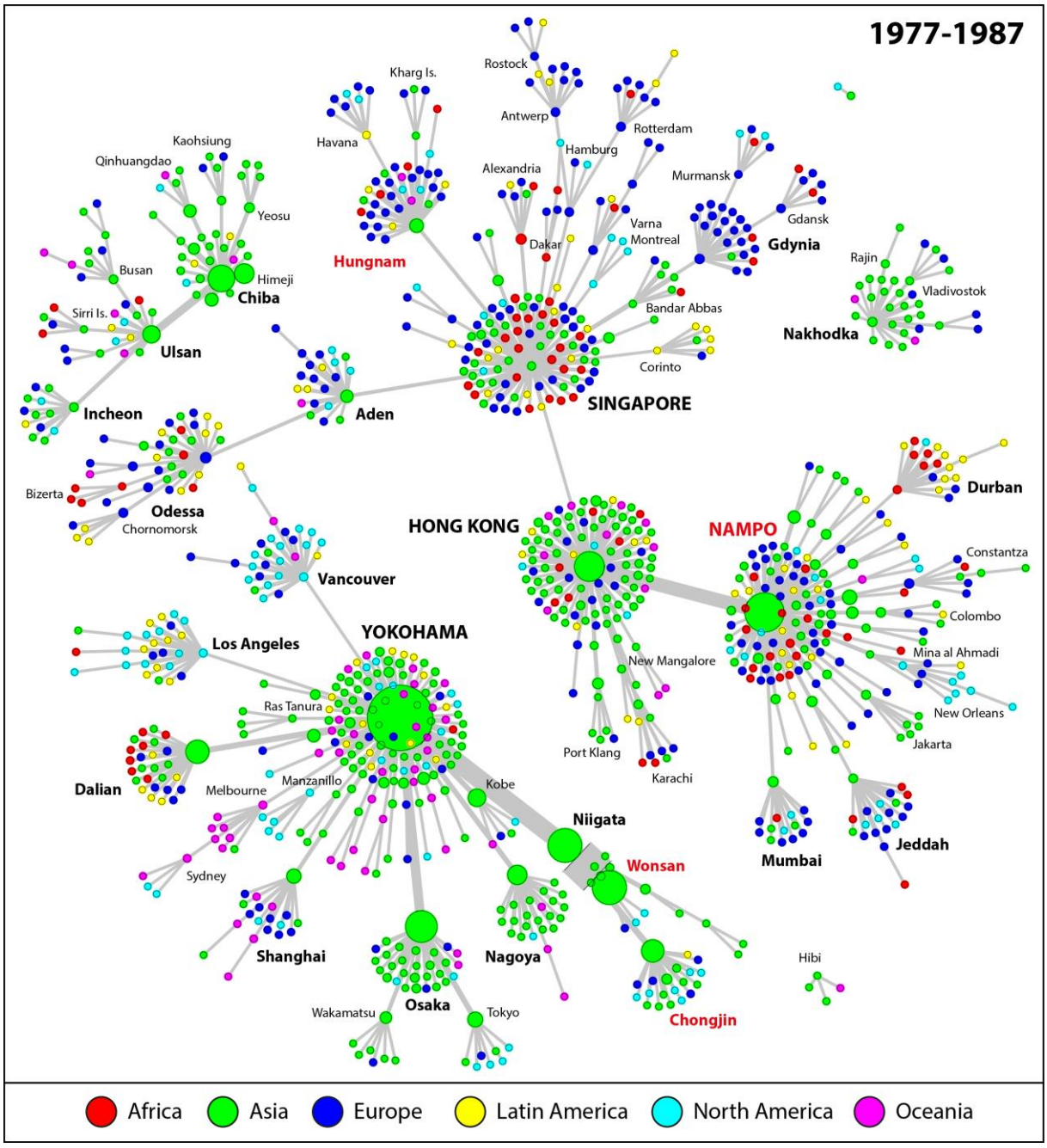
trade also occurred through shipping, as Iran (and Libya) was an important market for North Korean weapons, and numerous African countries received military equipment and training (Worden, 2008). Although they do not appear as hubs in the top figure, ports like Alexandria (Egypt), Bandar Khomeini (Iran), and Karachi (Pakistan) have important traffic volumes, with a high share of North Korean vessel traffic. Overall, the calls of North Korean vessels create a clear division of the world, between developed economies (North America, Western Europe, Australasia) and the rest.

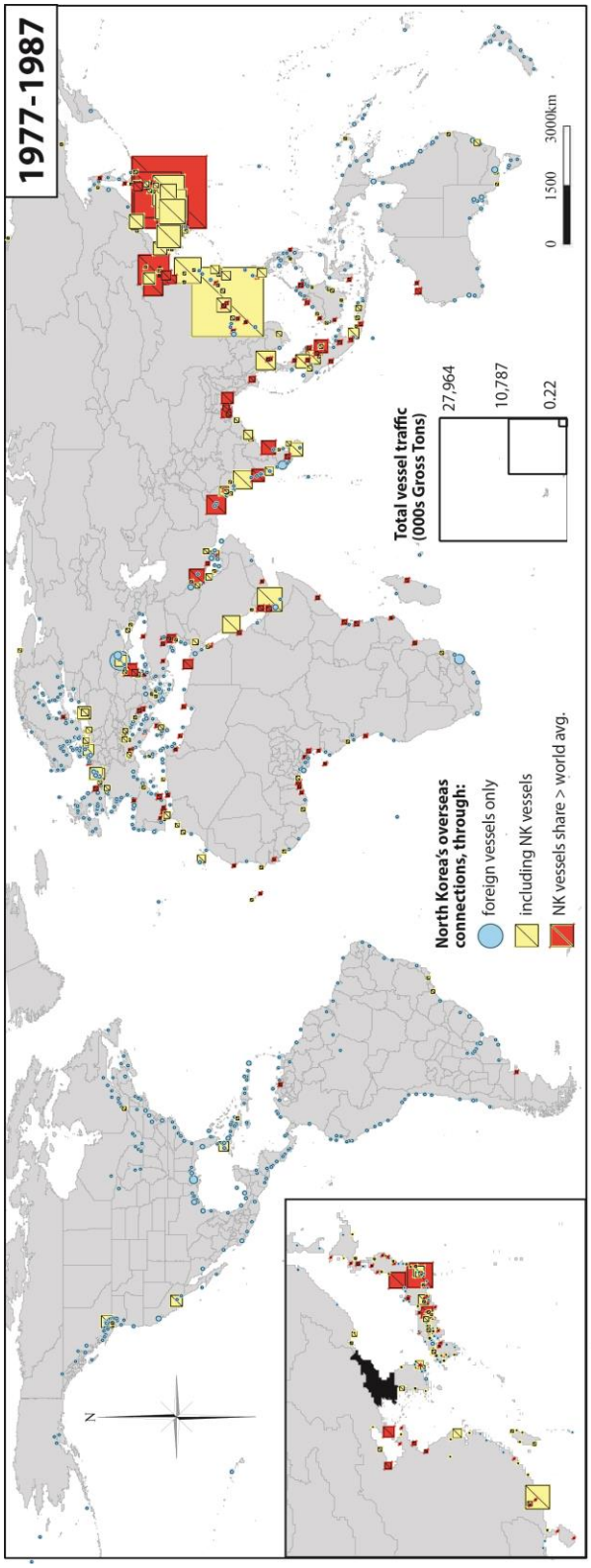
4.2. 1988-1998

The second period is marked by a drastic shift of connectivity. It corroborates the fact that Singapore had become North Korea's vital link to the outside world, as a prime intermediary hub to connect the global maritime network. Singapore is in itself a hub to all continents, while it provides access to secondary hubs in Europe (Odessa, Constanza, Saint Petersburg, Gdynia, Hamburg), and superseded Yokohama for the Asia-Pacific connection (North America's West Coast) and even the Atlantic (Santos, Rio Grande). Such a shift had the effect of highly reducing Nampo's connectivity, both in terms of the number and geographic extent of its direct flows, which are now bound to Asia, except the link with US Gulf ports (New Orleans, Houston). Its secondary hubs remain within Northeast Asia (Nagoya, Dalian, Kisarazu, Oita) and Hong Kong has also lost ground to Singapore. The second largest nodal region is essentially a Japanese subsystem (Yokohama, Osaka, Tokyo, Chiba, Sakai, Kobe, Kashima), with a sustained largest flow between Wonsan and Niigata, which also primarily connects Chongjin and Hungnam. Through Niigata and Tokyo, this component provides transitive access to Latin America and Havana in particular. The two smaller nodal regions are self-centered around South Korean ports (Busan, Incheon, Ulsan) and Russian ports (Vladivostok, Nakhodka, Vanino). These components are restrained mainly to local traffic, although Busan and Vladivostok are more diversified geographically.

Japan to their families in North Korea (Blomquist and Wertz, 2015).

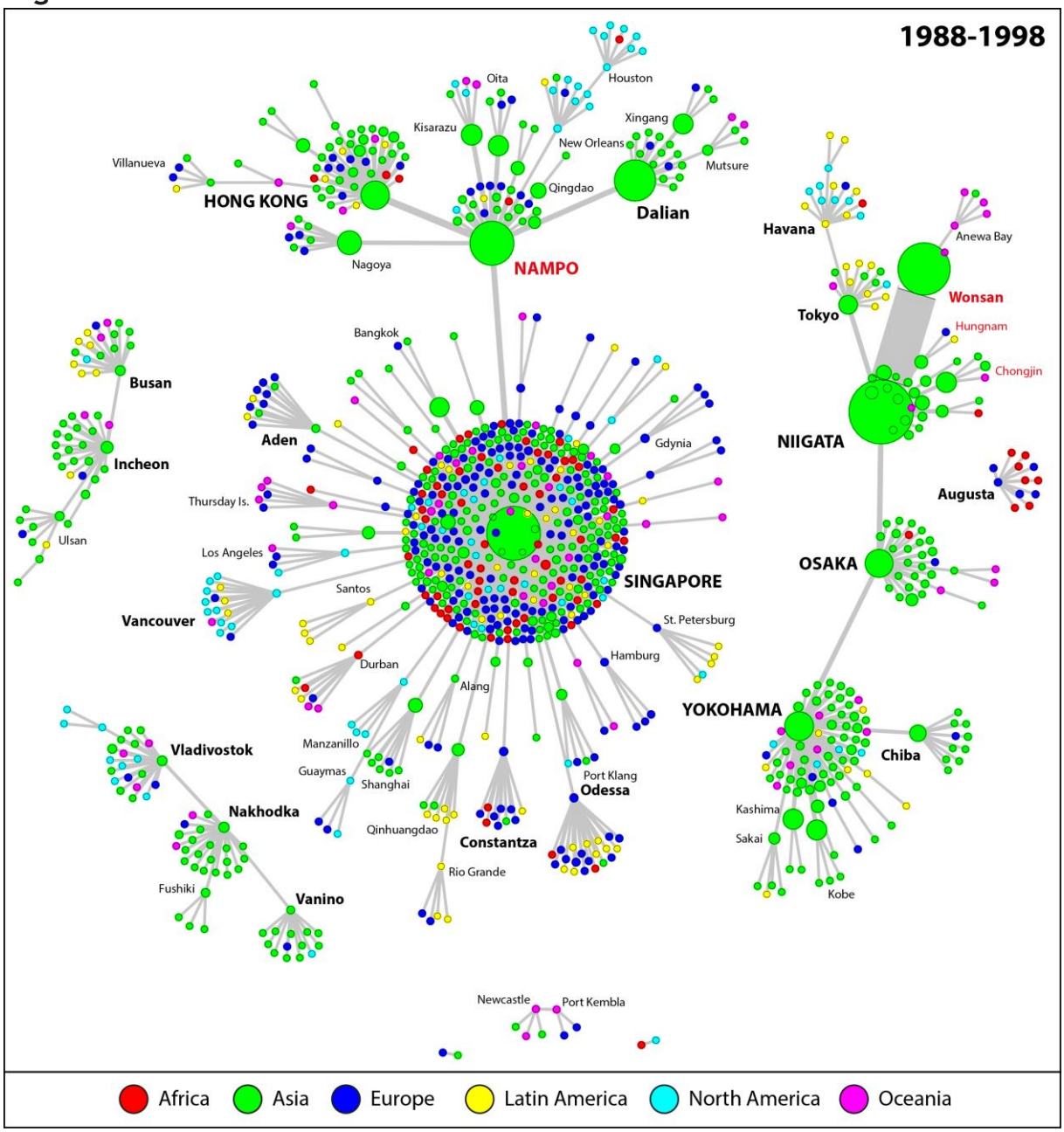
Figure 4 – Nodal regions in the global North Korean maritime network

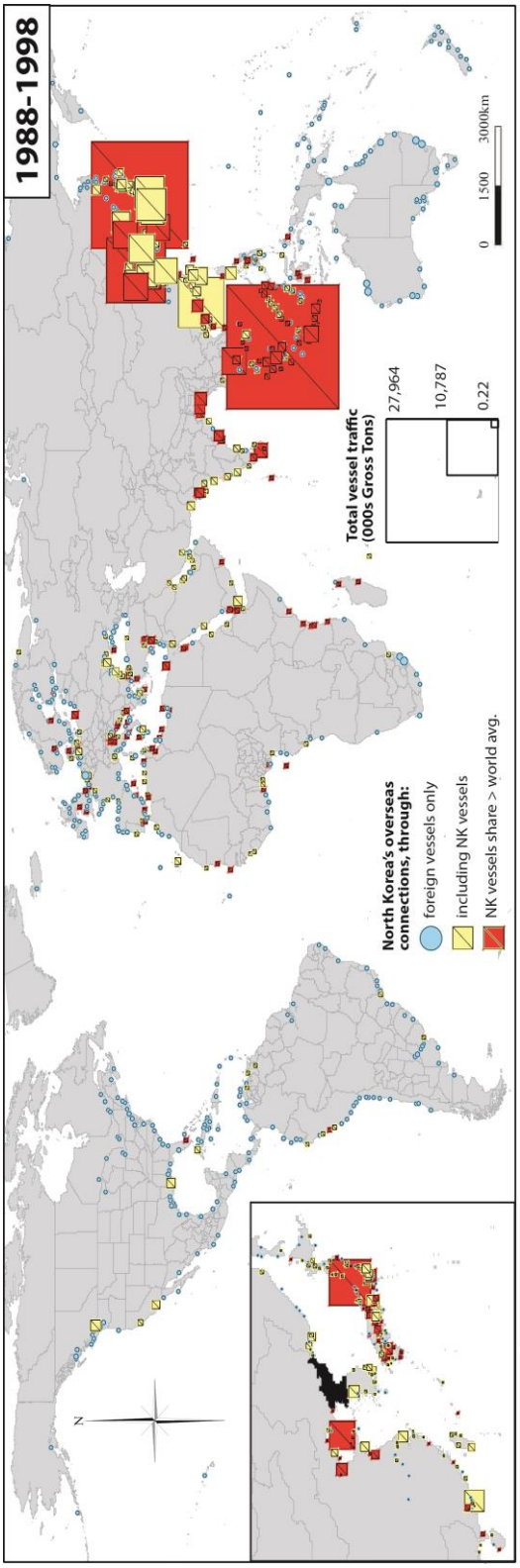




Source: own realization based on Lloyd's List data and TULIP software

Figure 4 -continued





Source: own realization based on Lloyd's List data and TULIP software

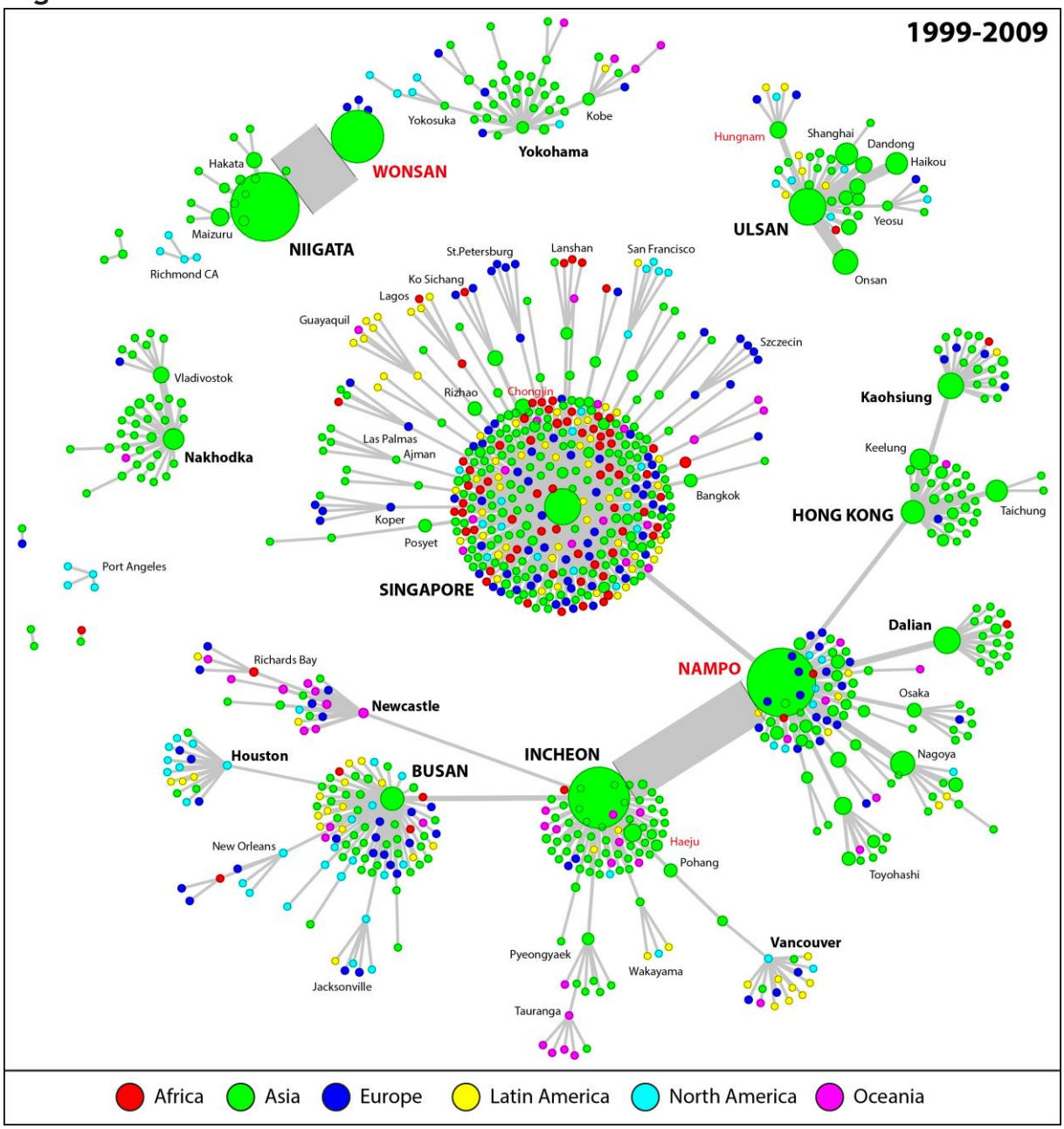
4.3 1999-2009

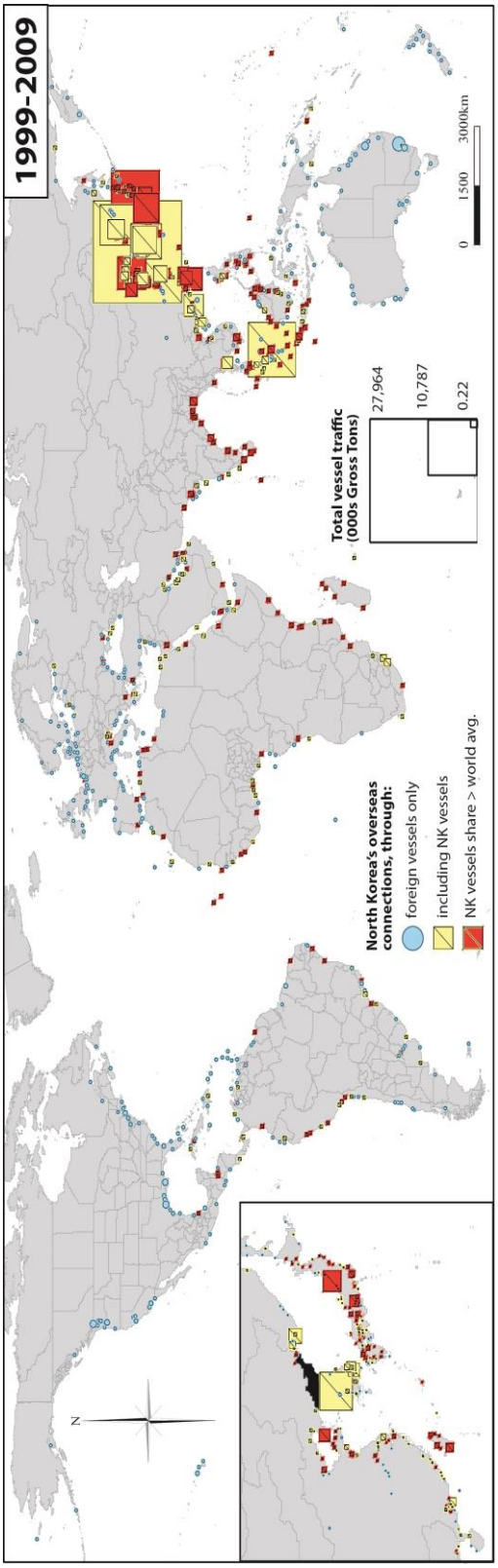
The third period marks another turn in the distribution of connectivity. This time, most hubs belong to the same giant nodal region, where Singapore still acts as the leading international node connecting all continents, with a direct link to Nampo. We still observe a legacy of Soviet trades, with the appearance of Koper, Szczecin, and Saint Petersburg. Hong Kong has become a secondary, local hub, like most Japanese hubs, as Yokohama stands apart with Kobe and Yokosuka. Still, Niigata generates very high traffic, and connects Wonsan through the largest flow of the period. While Nampo's connections with Hong Kong and Singapore are relatively weak in terms of traffic size, a huge change is the shift of most of its traffic towards Incheon, which now plays with Busan, Pyeongtaek, and Pohang a strategic role to connect other continents, especially the Americas and Oceania. Nampo's direct connections have diversified compared with the second period, in a context of reform and openness. But it is interesting to note that hubs other than South Korean ones remain connected primarily to Asia (Toyohashi, Nagoya, Osaka, Dalian, Hong Kong, Taichung, and Kaohsiung). Wonsan-Niigata is still the largest flow link, but constitutes a separate nodal region. Ulsan dominates a group of other Korean ports of which Yeosu, Onsan, Hungnam but also Chinese ports. Another separate group appears with Nakhodka at the center.

4.3. 2010-2021

In the most recent period, one single nodal region concentrates again most of the ports. This time the highest traffic occurs between Nampo and Dalian, underlining the shift under China's influence, which occurs by road but also by shipping for oil imports and coal exports (Scarr and Cai, 2017). Chinese ports are grouped together in the left part of the figure, concentrating in North China. On the other side, the second largest link is between Nampo and Incheon, the latter being an international hub (unlike Dalian) connecting other continents either directly (Newcastle, Gladstone) or indirectly through Nagoya, Pyeongtaek, Singapore, Port Klang and even Santos in Brazil. These two subsystems coexist and are complementary. Interestingly, Newcastle is specialized in coal exports (94% of its traffic in 2011), while Gladstone is the world's fourth leading port for coal exports (70% of its exports).

Figure 4 -continued





Source: own realization based on Lloyd's List data and TULIP software

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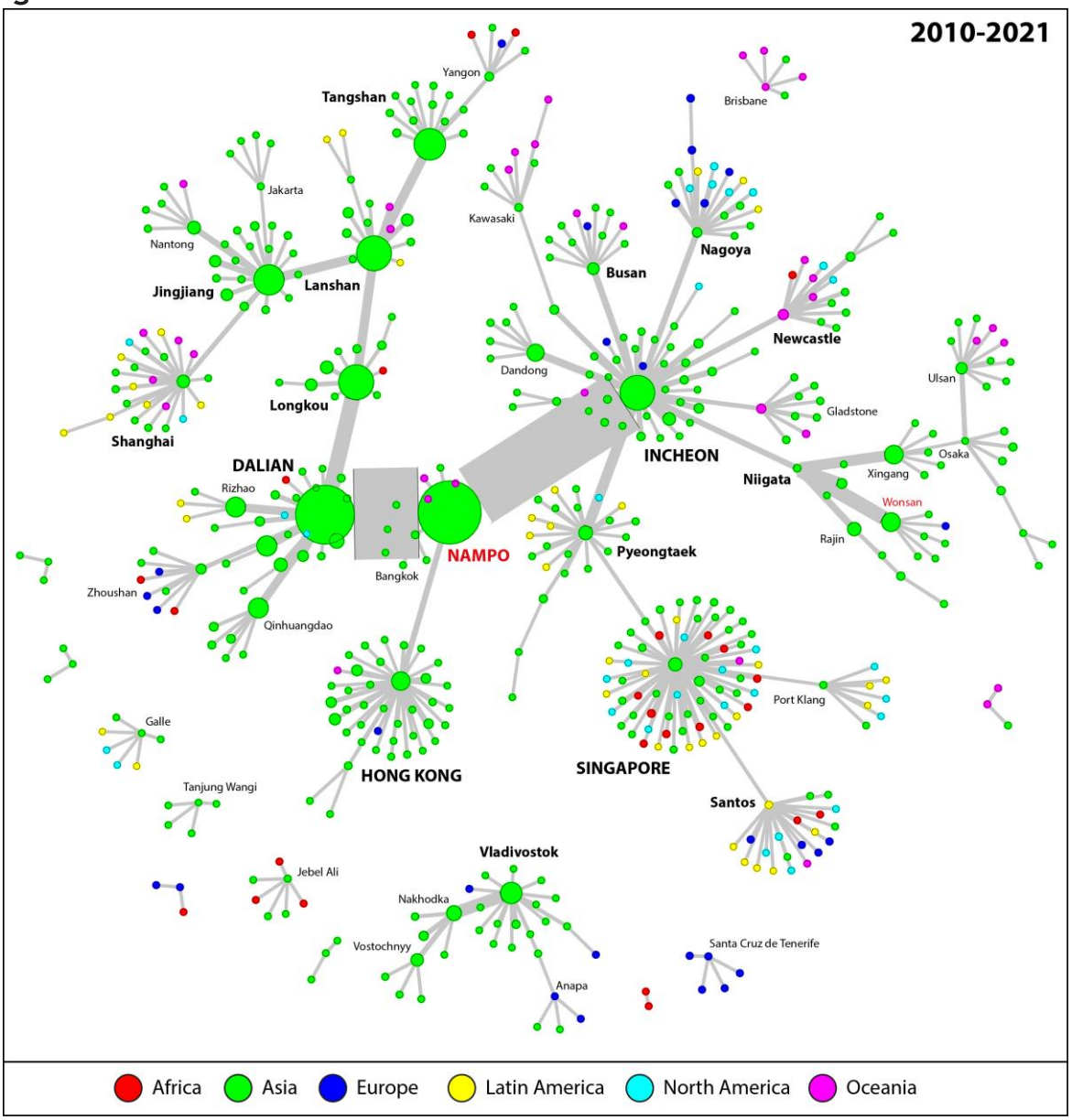
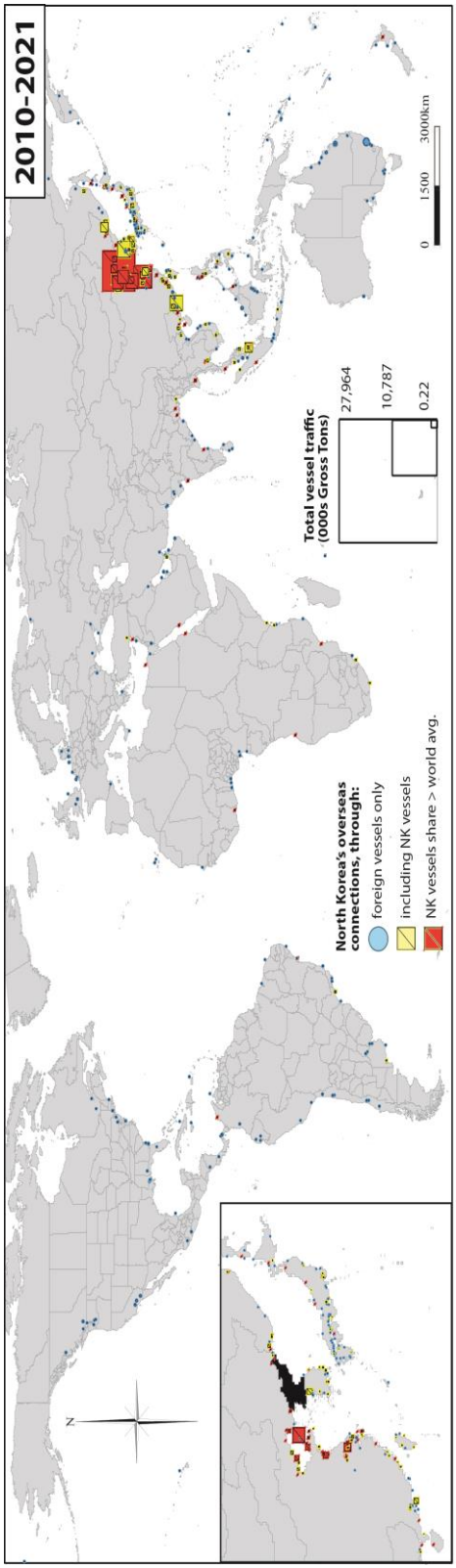




Source: own realization based on Lloyd's List data and TULIP software

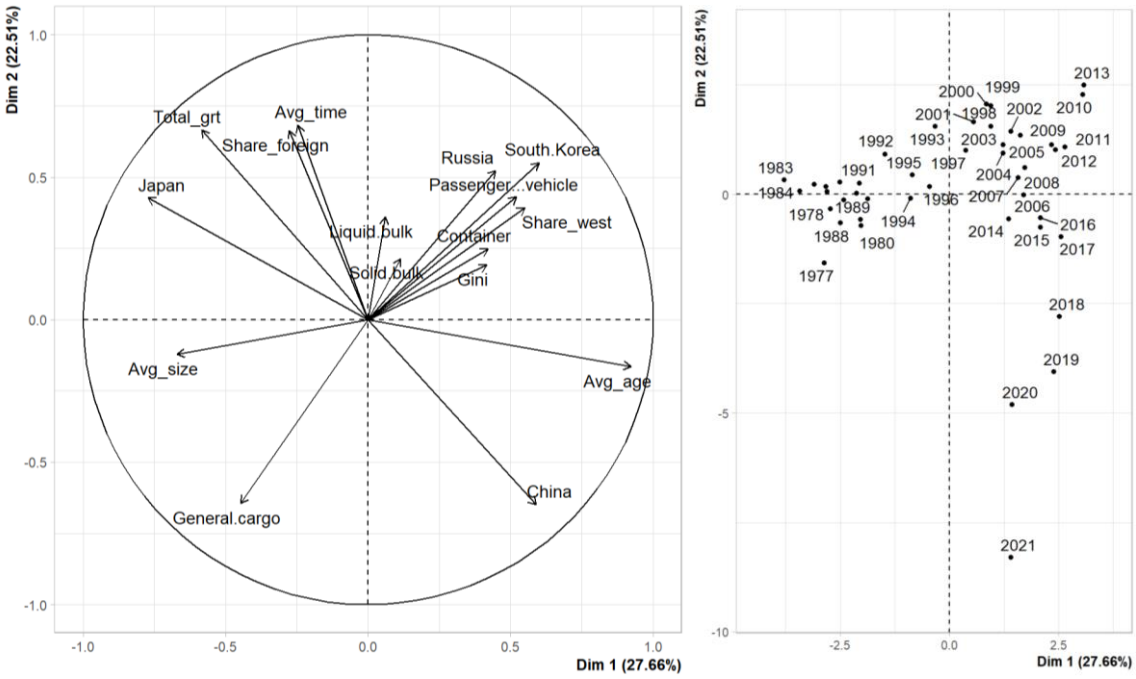
Some of the important Chinese ports emerging in this period were reported in the news, mainly in relation to illicit coal trade (Cho and Oh, 2020). For instance, North Korean vessels were seen in Tangshan (Blanchard and Ruwitch, 2017) and Jingjiang, Bayuquan, Ningbo-Zhoushan carrying coal from the port of Taean in North Korea (United Nations, 2021).

5. Shipping dynamics, economic dynamics, and political factors

5.1 Classification of shipping dynamics

In this part of the research, we apply a factor analysis on 17 variables that characterize North Korean shipping, over 45 years, each year being an observation. The results are statistically significant, as 79% of total variance is captured by the first five factor loadings with eigenvalue > 1. In addition, observations (years) are distributed along the first two factors in a chronological fashion from bottom-left to bottom-right, suggesting that North Korean shipping followed a continuous rather than a chaotic evolution, despite highly contrasted economic and political contexts (Figure 5).

Figure 5 - Factor analysis of North Korean shipping dynamics



Source: own realization based on Lloyd's List data

Most variables are well represented along these two factors, highlighting interesting associations and oppositions. A hierarchical clustering is applied on the five first factor loadings to summarize the findings and verify the role of political factors.

Three clusters of observations were obtained, delimited in time by crucial turning points. The first (1977-1996) and second cluster (1997-2017) overlap at a period of mass starvation and general economic crisis caused by external and internal factors. The loss of Soviet support, after the collapse of the Eastern Bloc, provoked food production and imports to decline rapidly, aggravated by the lack of currency to purchase oil and fertilizers for an increasingly isolated economy. Devastating floods in 1995-1997 destroyed arable land, harvests, and grain reserves, while damaging 85% of power generation facilities, coal mines, and transport infrastructures.

The third cluster (2018-2021) is relatively short in time but marks North Korea's "ultimate decline" until today, aggravated by international sanctions imposed, notably, by the United Nations in 2016-2017[3]. More specifically, the United Nations passed three successive resolutions to cap and finally ban the export of gold, vanadium, titanium, rare earth metals, coal[4], iron, copper, nickel, zinc, silver, lead, and seafood. As a result, North Korea operates illicit trade of oil and coal, using floating transshipment platforms in other countries' territorial waters to move commodities between vessels at sea, or ship-to-ship transfers (Kube and Luce, 2018; Koettl, 2021).

Each cluster is characterized by statistically significant variables in positive or negative ways as seen in Table 2. The first cluster (1977-1996) positively correlates with Japan, rest of world, total traffic, general cargo, and share of foreign vessels. Based on the most representative variables with negative signs, we conclude that during this period, the North Korean fleet is younger, traffic is more concentrated on the East

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3 Since North Korea's first nuclear test in 2006, four sanctions had already been passed by the UN, destined to control the export of military supplies and luxury goods, and to inspect suspected vessels.

4 Coal is highly strategic for North Korea, notably anthracite, which generates 10% of the country's GDP, and for which North Korea has surpassed Vietnam in 2013 as the top global exporter. However, the United States consider that coal, as a key revenue generator, in fact helps funding North Korea's weapons of mass destruction programs, and that its extraction uses forced labor from prison camps.

coast, but is more evenly distributed across the country than in later periods (lower Gini coefficient). This profile is the one of a wealthy economy, before the crisis.

The second cluster (1997-2016) positively correlates with South Korea, Russia, passenger and vehicle, West coast, container, and Gini. It is opposed to average ship size, general cargo, rest of world, and Japan. This confirms the shift of traffic towards Nampo and Haeju, in a context of active inter-Korean collaboration, while South Korea also became North Korea's transshipment hub for containers. This confirms the collaboration dynamics put in place with South Korea (The Korea Herald, 2016) and Russia (Zakharova, 2016) during this period.

The last cluster (2017-2021) positively correlates with China, ageing fleet, and general cargo. It is opposed to the share of foreign vessel traffic, total traffic, average turnaround time, and to all other trade partners including rest of world. This underlines the shrinkage of maritime connections in parallel with a reorientation of trade relations with nearby China.

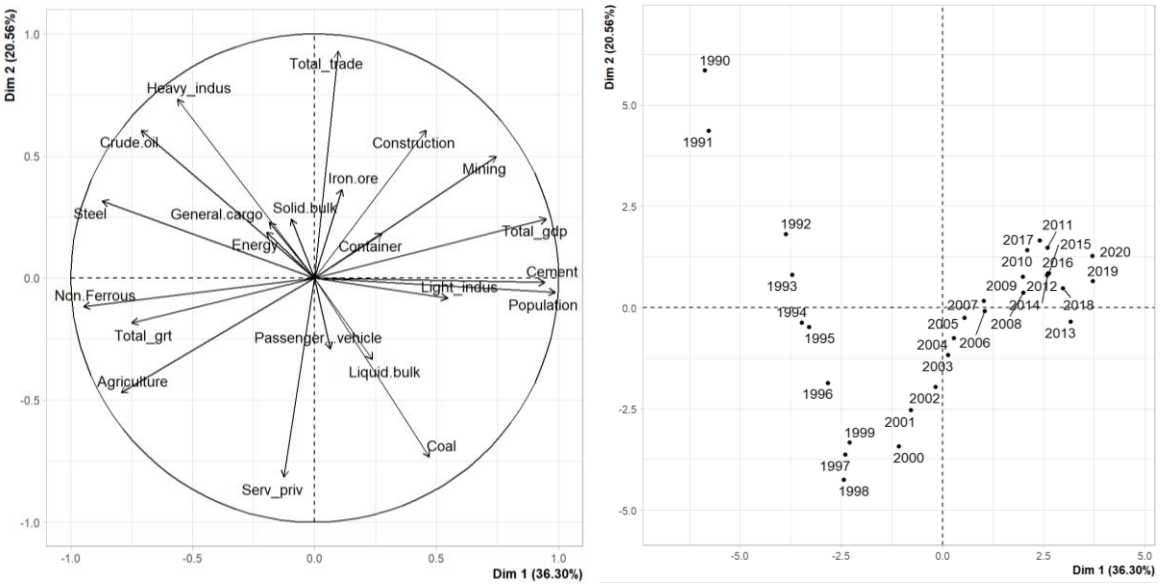
5.2. Maritime trade and economic development

This part of the analysis focuses on a shorter, more recent period (1990-2020) mainly due to the unavailability of economic data prior 1990. It applies a factor analysis on a mix of 21 shipping of shipping and economic data to unravel their possible interlinkages, so as to verify the potential role of maritime transport in economic development. Contrary to the previous analysis, traffic types are considered by their volume, not by their share (Figure 6). The results are statistically significant, with the five first factor loadings concentrating no less than 84.3% of total variance with eigenvalues > 1.

The hierarchical clustering analysis sheds more lights on the interlinkages among variables along with three clusters, each corresponding to a continuous time period. The first cluster (1990-1993) positively correlates with oil imports, the heavy industrial sector, steel, non-ferrous metals, and total trade. The lack of interlinkage between oil imports and liquid bulk shipping is explained by the fact that before the crisis, especially during the industrial peak of the 1970s and 1980s, North Korea used to import oil from China and the Soviet Union by land at below-market prices. While basic metals represented one-third of total exports in 1992 (Jeong and Bang, 2010), one cannot observe a relationship with solid bulk traffic. This is partly explained by the fact

that 47.5% of basic metal exports went to China, using land transport.

Figure 6 - Factor analysis of shipping and economic data



Source: own realization based on Lloyd's List data and Bank of Korea data

The second cluster (1994-2003) corresponds to a period of deep crisis. It positively correlates with the primary sector, private services, non-ferrous metals, and total shipping traffic. This period is marked with agricultural and food assistance to North Korea, notably through the World Food Programme (WFP) and from the United States also for medical supplies (Manyin, 2005). By 1996, it imported only 40% the level of 1990 oil imports from Russia, China and Iran (Ahn, 2005). This was compensated through the KEDO project, which had delivered more than one million tons of heavy fuel oil in the late 1990s to North Korea in exchange for an end to the nuclear weapons program (Wit, 1999). Between 1995 and 2003, the United States provided over $400 million to KEDO, of which nearly $380 million went towards heavy fuel oil shipments. South Korea used the Sokcho-Yanghwa maritime route to ship personal and materials to/from the Light Water Reactor project site in Kumho[5]. Yet, no particular traffic variable belongs to this cluster,

5 However, the impact of KEDO on port traffic is limited, as related oil shipments fueled North Korean power and thermal facilities located in the West (i.e., Nampo, Songnim, and Sonbong), and Chongjin facilities was supplied via Seonbong port (United States General Accounting Office, 1999).

except total traffic.

The third cluster (2004-2020) is very contrasted internally, from inter-Korean cooperation (e.g., the maritime agreement signed in 2004) to UN sanctions from 2006 to 2017. It positively correlates with total GDP, population, mining, cement, construction, total trade, and light industries. Such a profile is realistic as it corresponds to the establishment of the company ORASCOM near Pyongyang for instance, to use Nampo port for the shipping of cement, notwithstanding related mining operations and a dedicated hydroelectric power station near the plant (Griggs and Fidler, 2007). This cluster is not marked by any specific shipping variable. This may come from the fact that trade with China has increased during this period, of which 80% goes across the Dandong-Sinuiju land border. Although it increased the volume of shipping, the transshipment of bituminous Siberian coal through the Rajin-Khasan border (Russia) in the mid-2010s did not relate with the local economy (Yi, 2015)[6]. This project comes from a joint venture in 2008 with Russia (RasonKonTrans) that enabled the construction of the line by Russian Railways, and the export of Mongolian coal as well.

This analysis does not show any specific correlation between economic and shipping trends. Maritime transport seems to have been most significant (total traffic) during the phase of acute crisis (second cluster), therefore to import aid from overseas, but not for economic development.

5.3. Does shipping influence economic development?

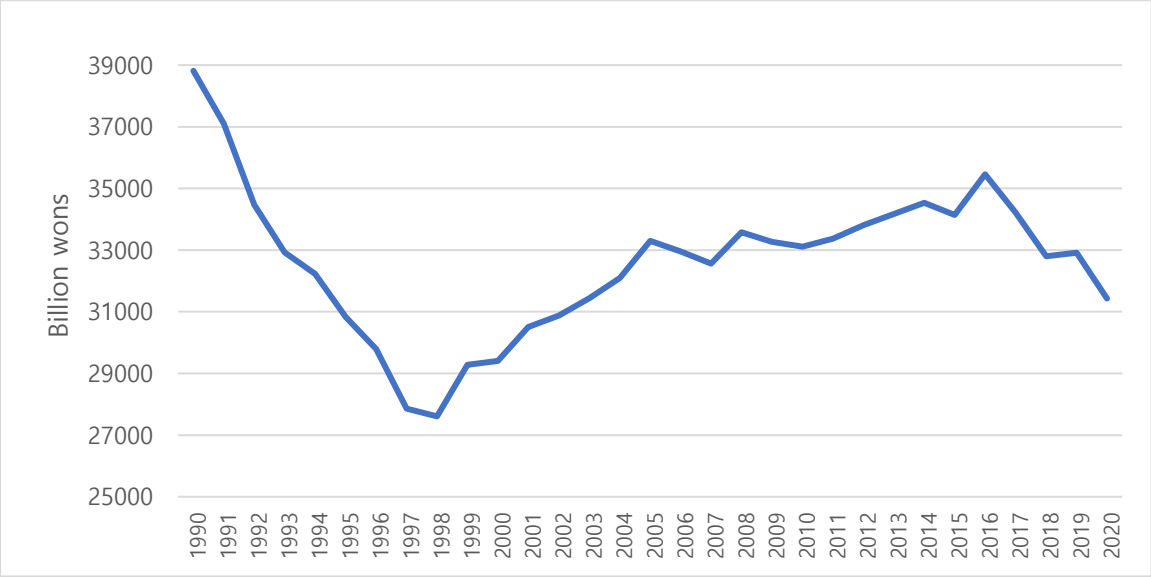
This last analysis wishes to shed more light on the possible influence of shipping and other economic indicators on the evolution of North Korean GDP between 1990 and 2020. The dependent variable is GDP, and its evolution is provided in Figure 7. Independent variables include shipping traffic by main vessel type and main trade partner, and production of

6 Considerably used by the Soviet Union before 1991, Rajin port had been the target of foreign investment in the 1980s through a joint venture law (1984). However, the chosen investments after the creation of the Rajin-Seonbong free-trade zone (Raseon) did not have much impact on the port – mainly services (Jo and Ducruet, 2007). The need for a better access to the sea for Jilin province (China) motivated Hunchun city to form a joint firm with Raseon in 2005 and sign port terminal concession agreements (Kim, 2007), with the first coal exports (8840 tons) reaching Shanghai, Lianyungang, and Guangzhou in 2013.

different commodities. They are completed by total trade, population, volume of crude oil imports, and the two yearly dummies for nuclear and missile tests.

The results of the different models (Table 2) are, overall, statistically sound. In model 1, which considers all variables, the most significant variables are total trade and population (positive influence on GDP). They overwhelm other variables, which are poorly represented. Only general cargo traffic and cement production stand out, with a negative influence on GDP. As a matter of fact, general cargo[7] has been the dominant traffic type for North Korea, but with much larger amounts in the early period. Three variables can be added to the discussion as "nearly significant". Solid bulk traffic, the second largest by its volume, and container traffic, underdeveloped in North Korea, have both positive (albeit negligible) influence on GDP. Solid bulk may correspond to the surge in coal traffic in the late period, while container traffic waxed and waned rather than truly increased, with a slight peak in the late 2000s and early 2010s mainly due to inter-Korean cooperation. Interestingly, the analysis confirms that missile tests had a negative influence on GDP.

Figure 7 – Evolution of North Korea's GDP, 1990-2020



Source: own realization based on Bank of Korea data

7 General cargo corresponds to products carried neither containerized nor in bulk, such as steel plates, wood products, project cargo (large machine parts), scrap, etc. but also any product in box, pallet, package, box.

In the second model, we see that shipping with South Korea has the strongest influence on GDP, followed by China. While inter-Korean general trade halted in 2010, it was gradually replaced since 2004 by economic cooperation projects, namely the Gaeseong Industrial Complex (GIC). Located inland in North Korea, this specific free-zone was served only by trucks, until its closure in 2016 by South Korean authorities, following the fourth nuclear test. Maritime transport with South Korea is more likely to have played a role before 2010, with a regular growth since the mid-1990s, a fast growth after the signature of the maritime agreement (2004) from 1.1 to 6.8 million tons between 2004 and 2005, and a near-disappearance after 2008, as a "tourist was shot by North Korean soldiers in July 2008" in Mount Geumgang (Lee et al., 2020). Total traffic is near to significant with a negative influence, given the drastic decline of maritime activity over time.

In the last model (3), total traffic and general cargo are highly significant, with a negative influence on GDP, whereas container traffic scores in similar ways than in model 1. The significance of South Korea and China has increased, and Japan appears as very significant as well but with a negative influence on GDP. As seen in previous sections, Japan-related traffic had been stronger in the early period, and stopped after 2006 after Japan unilaterally banned all trade with North Korea due to the 2006 missile test over the East Sea.

6. Discussion and conclusion

This research is the first to have investigated the evolution of North Korean shipping at the global scale, over more than four decades, while checking its relationship with the economic development of this relatively unknown country, recently coined "the last transition economy" (Koen and Beom, 2020), and often seen as the world's most closed economy.

The analysis of connectivity depicted the rapid shrink of the number of linkages and their geographic reach over time. The structure of network relationships evolved towards an increasing dependence upon neighboring hubs to connect the rest of the world, from Hong Kong to Singapore, Incheon, and Dalian in China. The joint analysis of shipping and economic indicators provided limited evidence of an impact of shipping on economic development, but confirmed the growing importance of China in North Korean trade and economic development.

Table 2 – Multiple linear regression results

t values	Models	1		2		3	
	(Intercept)	-6.931	***	8.839	***	11.322	***
Socio-economic	Total_trade	4.492	**	-		-	
	Population	6.603	***	-		-	
Shipping	Total_grt	-0.968		-1.821	.	-2.157	*
	Container	2.078	.	1.652		2.025	.
	General_cargo	-2.614	*	-1.691		-2.183	*
	Liquid_bulk	-0.427		-0.673		-0.720	
	Solid_bulk	2.022	.	1.481		1.682	
	China	1.395		3.098	**	4.438	***
	Japan	-0.319		-3.698	**	-4.532	***
	South_Korea	0.390		4.173	***	5.106	***
	Russia	-0.782		-0.202		-0.430	
	Rest_of_world	0.847		0.923		1.424	
Production	Coal	-0.893		-		-	
	Iron_ore	0.484		-		-	
	Non_Ferrous	0.572		-		-	
	Steel	-1.597		-		-	
	Cement	-2.270	*	-		-	
	Fishery	-1.693		-		-	
Other	Import_oil	1.258		0.114		-	
	Nuclear_tests	-1.618		-0.393		-	
	Missile_tests	-2.123	.	0.687		-	
	Multiple R-squared	0.9985		0.9192		0.9162	
	Adjusted R-squared	0.9949		0.8573		0.8743	
	Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1						

Source: own realization based on Lloyd's List data and Bank of Korea data

Is further research on North Korean ports and maritime transport desirable? The first inter-Korean summit in 2000 and the economic reforms of 2002 created a window of opportunity for scholars to study North Korean ports and maritime transport. Since then, however, the escalation of international tensions inevitably shifted the focus from economic development to security and geopolitical issues. In addition, the bulk of North Korea's foreign trade increasingly occurred by road transport, to such an extent that shipping activities have nearly disappeared today, also due to recent UN and other sanctions. With extreme typhoons, floods and droughts suffered by the country in the

late 2010s and early 2020s, the regime currently faces potential food shortage and malnutrition. Impacts from the pandemic are also felt, as the closure of the border with China hampers the activity of humanitarian organizations. Such parameters will put maritime transport in parentheses in the years to come. Nevertheless, further research may approach the statistical analysis of the observed trends in different ways to find more evidences, such as by considering GDP growth rates instead of GDP as dependent variable, and adding other independent variables, such as GDP per capita or other economic indicators.

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