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The Sustainable Relationship between Navigation of Arctic Passages, Arctic Resources, and the Environment

Chunjuan Wang[1,2], Dahai Liu[2], Meng Xu[2,3], Ying Yu[1,2], Xiaoxuan Li[2], Junguo Gao[2] & Wenxiu Xing[2]

[1] School of Ocean Sciences, China University of Geosciences, Beijing, China

[2] The First Institute of Oceanography, State Oceanic Administration, Qingdao, China

[3] School of Economics, Ocean University of China, Qingdao, China

Correspondence: Dahai Liu, The First Institute of Oceanography, State Oceanic Administration, Qingdao, ON.266061, China. Tel: 1-386-480-7051. E-mail: liudahai@fio.org.cn

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Abstract

The Arctic passages are economically important waterways connecting North America, Western Europe, and East Asia. Global climate change is melting the Arctic sea ice and will improve the navigability of the Arctic passages. The opening of the Arctic route will facilitate the exploration and development of Arctic resources, which can alleviate the energy crisis, but it may ignite a worldwide "Arctic resource war". Besides, the navigation of the Arctic passages will also burden the Arctic eco-environment and trigger a wave of eco-environmental effects in the Arctic region include exacerbating environmental pollution, threatening survival of life, intensifying climate change, changing local production and lives, even worldwide. On this basis, this study uses a system dynamics analysis of positive and negative effects to review the resource and environmental effects due to opening the Arctic passages and proposes the measures to ensure the resource and environmental sustainability.

Keywords: Arctic passages, navigation, resource, environment, sustainability

1. Introduction

Currently, the Arctic sea ice is melting twice as fast as the average rate of global warming—and this rate is accelerating. In September 2012, a National Snow and Ice Data Center observation reported a record summertime low for the Arctic sea ice area. The Arctic melt season has ended, and the sea ice extent is now increasing after reaching the fourth lowest minimum on record on September 11,2015 (NSIDC,2015) . It has been predicted that by approximately 2020, the Arctic region may be completely ice free during the summer months (Ministry of Science and Technology of the People's Republic of China, 2012). As the Arctic sea ice melts, the navigability of the Arctic passages will improve, bringing commercial navigation closer to reality. Meanwhile, the rich natural resources of the Arctic region and the attractiveness of the Arctic passages themselves also add to the allure of commercial navigation.

The massive commercial gains to be earned from navigating the Arctic passages will lead to global competition to develop the Arctic region's energy resources and for navigation rights to the Arctic passages. Inevitably, the impending navigability of the passages and the exploitation of energy resources will impact the fragile Arctic eco-environment. As natural resources and the environment are major factors affecting human development in the 21st century, the Arctic region's future development after the Arctic passages become navigable will depend on achieving a balance between energy resource exploitation and maintaining the eco-environment. Therefore, research must be conducted to determine the potential effects of navigable Arctic passages on both resources and the eco-environment to provide theoretical support for the reconciliation of resource development with environmental protection and to ensure the sustainability of the Arctic region in the process.

2. Navigability of the Arctic passages

The Arctic passages are marine routes running through the Arctic Ocean that connect the Atlantic and Pacific oceans. These passages include the Northeast Passage (NEP), the Northwest Passage (NWP), and Transpolar Passage (TPP), Figure 1. The NEP does not have a fixed route or internationally accepted beginning and ending points. In general, the NEP refers to the sea route that runs from Iceland in the west, crossing the Barents, Kara,

Laptev, East Siberian, and Chukchi Seas of the Arctic Ocean. It then traverses the northern waters of Eurasia, joining the North Pacific in the east by way of the Bering Strait. The NEP subsumes the Northern Sea Route, an area off the northern coast of Russia (Guo, P., 2011). The starting point of the NWP has not been agreed upon but is generally accepted to be the Davis Strait and Baffin Bay in the east. The NWP runs through the Canadian Arctic Archipelago waters in the west, traverses the Beaufort Sea north of Alaska, and reaches the Pacific across the Bering Strait. The TPP is the sea route that runs from the Bering Strait, past the coastline of Russia or North America, and reaches the Greenland Sea or Norway Sea by directly crossing the midpoint of the Arctic Ocean. As the center of the Arctic Ocean consists of dense sea ice, this passage will be the last sea route to be navigated. Currently, the TPP is mainly used for scientific expeditions and tourism (Yan, L., 2011).

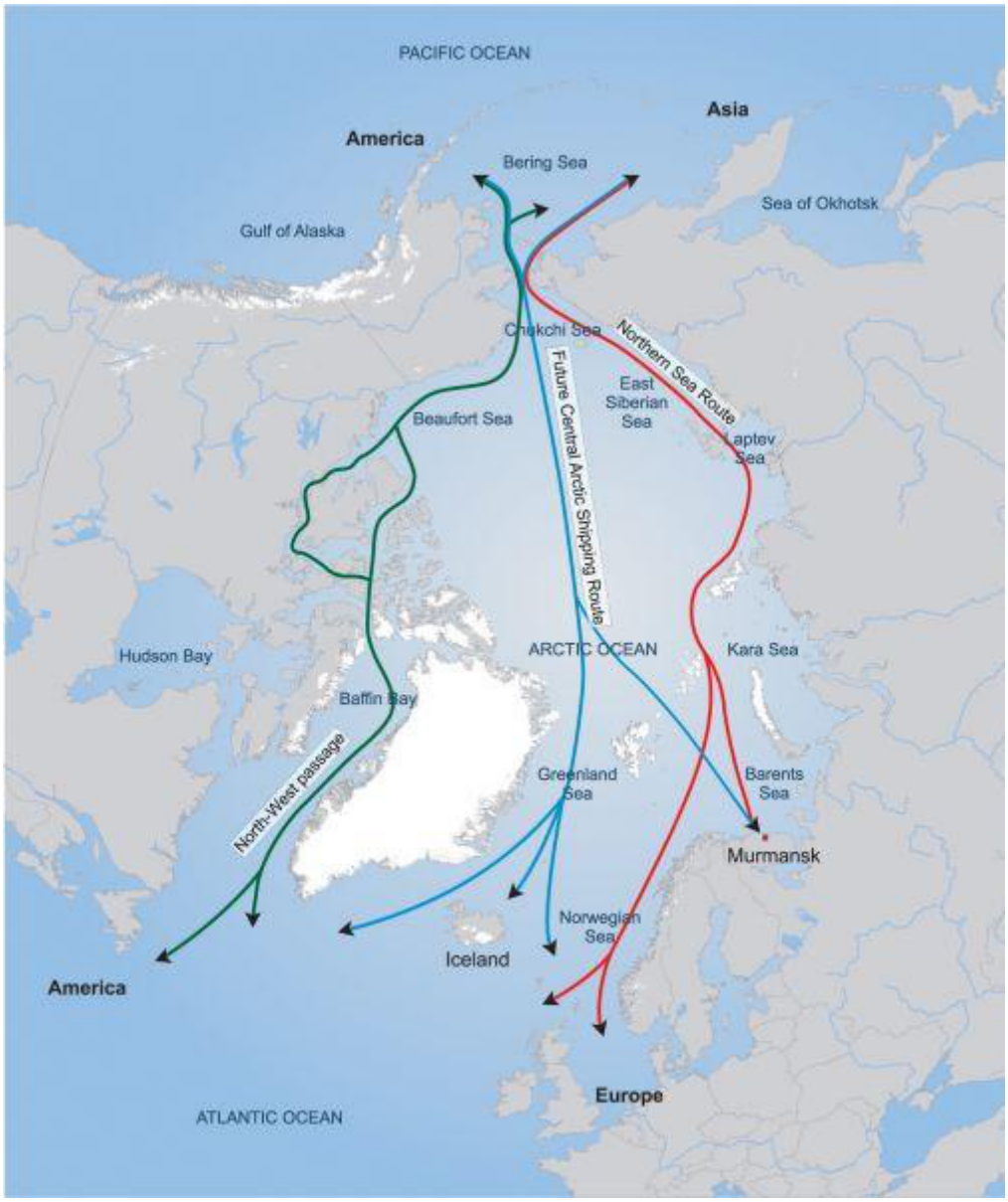

Figure 1. Map of the Arctic Passages

Source: http://neven1.typepad.com/blog/2012/12/looking-for-winter-weirdness-4.html

The accelerated melting of sea ice is shortening the timeframe for the opening of the passages and increasing the number of navigable days. An analysis of the relevant sea ice data during the 2009–2013 period reveals that the fully open period of the NEP typically extends from late August to early October, or approximately 40 to 50 days. The NEP's longest open period was recorded in 2011 at 82 days. The open period of the NWP is typically between early or mid-August and early October, with the total number of open days ranging from 50 to 60 (Li,

C., Li, M., Zhao, C., Zhang, L., & Tian, Z., 2014).

As the driver for the opening of the Arctic passages, global climate change may extend the number of navigable days, increase carrying capacity, and reduce the need for icebreaking, which would lead to steadily increasing traffic rates for commercial ships. The advantages of the Arctic passages have already attracted commercial shipping from and to ports around the world. In 2008, a cargo vessel named "The MV Calnilia Desgagnes" successfully sailed across the NWP, marking the advent of a new era for the Arctic passages (Montgomery & Heather, 2008). In the summer of 2009, two German cargo vessels made the first commercial voyage through the NEP (Schofield, 2009) . In September 2013, the Yongsheng Ship, owned by the COSCO Group, successfully navigated to the vicinity of the North Cape of Norway through the NEP, becoming the first Chinese commercial vessel to complete an Arctic voyage (Pettersen., 2013). In 2013, the number of commercial vessels using the NEP increased to 373 from 2 in 2009 (Zheng, Z., 2013) (see Table 1). Fewer ships have used the NWP because its waters, islands, and straits are more tortuous and complex; however, the number of crossings is increasing. Official statistics indicate that the number of ships passing through the NWP increased from 4 per year in the 1980s to 20 per year over the 2009–2011 period and reached 21 by 2012 (Zheng, Z., 2013) (Table 1, Figure 2).

Table 1. The number of open days and passing ships in the NEP and NWP (2009-2013)

		2009	2010	2011	2012	2013
Full open days of passage (d)	NEP	47	48	82	59	35
	NWP	13	57	62	64	Not opened
Passing ships (ship)	NEP	2	6	34	46	372
	NWP	20	20	20	21	—

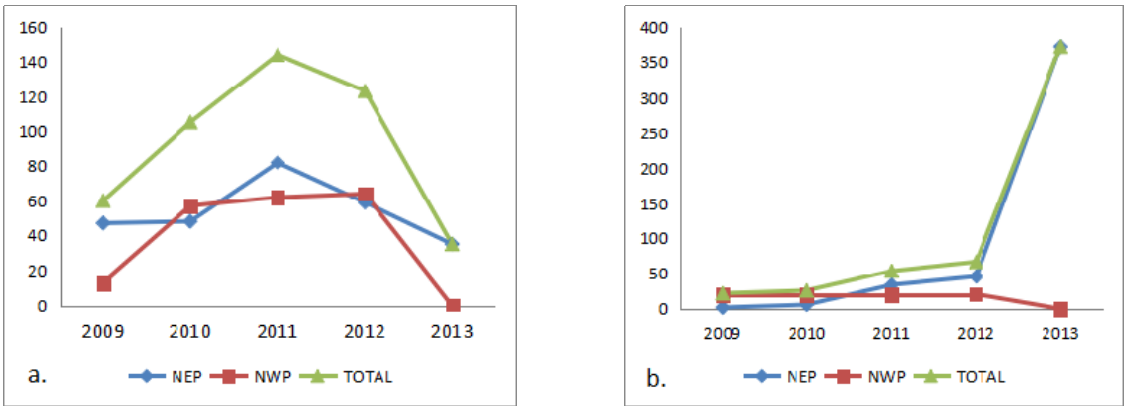

Figure 2. A trend chart showing the open days of the Arctic route and the number of ships passing through (2009-2013)

3. An Analysis of the Effects on Both Resources and the Environment Associated with the Navigation of the Arctic Passages

As the number of open days and the amount of ships using the Arctic passages increase every year, their full navigation is becoming increasingly possible. The rich resources in the Arctic region and the economic value of those resources will stimulate a growing appetite for petroleum, natural gas, natural gas hydrates, minerals, and other energy resources. The pursuit of the region's natural resources will inevitably encourage full navigation of the Arctic passages, thereby hastening its realization. In turn, the navigation of the Arctic passages will encourage further exploration and development of the Arctic region's resources. As navigation capacity increases and costs decrease, the Arctic passages will offer an economical and convenient marine route for exploitation of Arctic resources, making resource development increasingly scale-oriented and trade traffic more routine. Increased pollutant emissions from ships can be expected, whereas resource development will also lead to unavoidable environmental disruption: inevitably, there will be considerable negative impact on the fragile Arctic eco-environment.

3.1 Effects Arctic Passage Navigation on Arctic Resources

The Arctic region is endowed with rich natural resources, including a large stock of minerals, oil, and gas. According to the USGS Circum-Arctic Resource Appraisal published from 2008, the Arctic's oil and gas potential accounts for approximately 25% of the world's unproven reserves, with its oil alone accounting for approximately 13% of world reserves (USGS.2008). The Arctic region is home to 9% of the world's coal reserves. The region also contains tremendous stocks of gold, silver, copper, iron, lead, uranium, plutonium, cobalt, and other rare metals (Shi, C., 2010);The Arctic.2006). In addition, the Arctic's fishery, wind, water, and forestry resources have considerable economic value (Guo, C., 2010).

Altogether, the opening of the Arctic passages and the scale of Arctic resources make the Arctic one of the most attractive regions for resource exploration, exploitation, and transport for both Arctic and non-Arctic nations. Amidst the environmental changes and energy shortages, navigation of the Arctic passages will accelerate both global competition for Arctic resources and the speed of their exploitation. On one hand, the Arctic passages will provide marine channels for—and intensify—resource exploration and development. Initial exploration and development aimed at short-term economic benefits will inevitably have considerable impact on the fragile Arctic environment. On the other hand, the intensified exploration and development will increase the traffic volume of the Arctic passages and international reliance on these passages, thus making them true "Arctic energy channels" for transporting Arctic resources.

3.1.1 Navigation of the Arctic Passages Will Ignite a Worldwide "Arctic Resource War"

Russia, Canada, the United States, Denmark, and Norway have previously exploited Arctic resources. Marine oil and gas development in the Arctic dates back more than 90 years. In 2011, the daily output of Arctic oil and gas was equivalent to 8 million barrels of oil; the aggregate output was approximately 40 billion barrels of oil and 1100 trillion cubic feet of liquefied natural gas (LNG) (Lei, S. & Yin, J., 2014). Russia and the United States have been the main oil producers. The United States established the world's largest zinc mining base on the northwest coast of Alaska, while the world famous MMC Norilsk Nickel was established in the Eastern Siberian region of Russia. In addition, Canada has developed three diamond mines in the Arctic region within the last decade (Zhang, X., Li, W., & Wen, X., 2010).

A growing number of countries are competing for the Arctic passages and for the oil and natural gas resources associated with them. In 2011, more than 20 countries launched development projects in the Arctic region (Cai, H.). To maintain control over the Arctic and its resources, the five Arctic countries are now claiming their territories in the Arctic region while taking steps to position themselves to assert Arctic sovereignty. Canada has solidified its military position by building icebreakers and military bases in the region. The United States is trying to legitimize its sovereignty claims by strengthening scientific research in the Arctic. Denmark and Russia have both adopted Arctic development strategies in which the Arctic is used as a strategic energy base for national development (Niu, H.). Although geopolitical constraints have thus far confined the development of Arctic resources to the Arctic nations, these rich energy resources have already drawn the attention of many non-Arctic nations. For example, Korea is building an Arctic oil tanker and is also planning to build double-engine, double-propeller LNG vessels suitable for future Arctic voyages to transport oil and gas resources from the Arctic (Gu, Y.) .

3.1.2 The Arctic Passages Will Accelerate Exploration and Development of Arctic Resources as "Arctic Energy Channels"

With regard to global energy transport, the Arctic passages offer several advantages. They are the shortest paths connecting North America, Europe, and the Asia–Pacific and greatly shorten the sailing distance between different regions. Reduced sailing time lessens both the cost of fuel for ships and compensation to sailors, thus lowering transport costs. Furthermore, the Arctic passages are safer than traditional sea routes, as they are free from pirates and other threats.

These advantages ensure that the Arctic passages will play an important role in future global energy flows. As the primary passages to carry Arctic energy, the Arctic passages will boost the transportation of Arctic energy, assist in the exploration of Arctic resources, and accelerate the exploitation of oil, gas, and mineral deposits in the Arctic region. The relevant data suggest that Russia commands the largest share of the recoverable oil reserves in the Arctic region at 52%, followed by the United States at 20%, Norway at 12%, Denmark at 11%, and Canada at 5% (Aimin, S., 2015) (Figure 3). As Russia, Canada, and Norway are the largest stakeholders in the Arctic passages, the development of Arctic energy will increase their total energy production, their demand for energy transport, and consequently their reliance on the Arctic passages. This development will be particularly beneficial for Russia and Norway because the export of oil via the Arctic passages is becoming

urgent for these countries. In August and September 2010, Russia delivered 80,000 tons of crude oil to China across the Arctic passages. In December 2012, the oil tanker "OB River" successfully completed the world's first LNG transport across the Arctic passages (Zou, Z., 2014) . Both of these events demonstrate that the Arctic passages have already begun to provide new paths to ship Russia's energy. Studies have predicted that Arctic oil will account for approximately 26.5% of the world's total oil trade volume, whether it is shipped by sea, land, or pipeline (He, Y. & Zhou, C., 2013). Overall, the ever-increasing global demand for Arctic oil resources combined with the economy and security of the Arctic passages will both lead to increased international exploration and development of oil in the Arctic region and drive energy suppliers and traders to intensify the use of the Arctic passages for energy shipment.

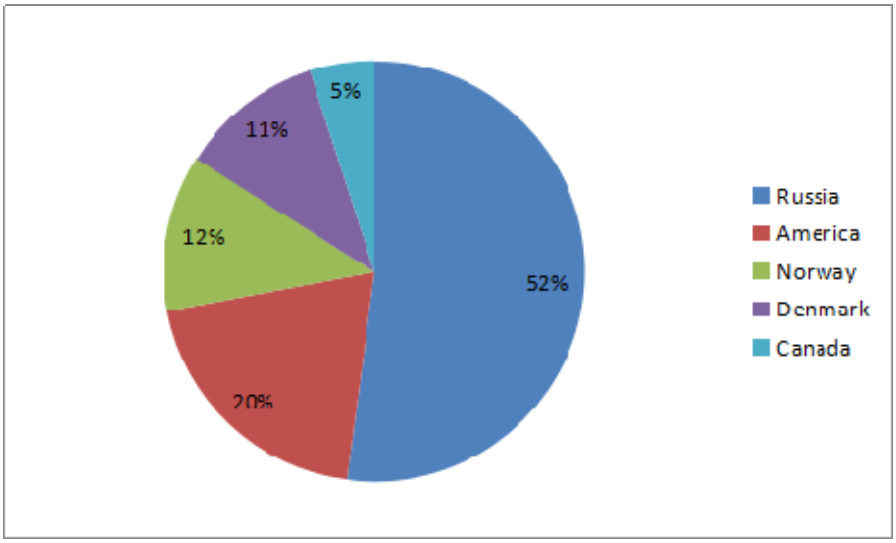

Figure3. The proportion of oil reserves in the Arctic

3.2 Eco-Environmental Effects Resulting from Navigation of the Arctic Passages

With year-round ice coverage, the eco-environment of the Arctic region is fragile. Moreover, its self-regulation and eco-restoration capacity are quite weak. Under pressure from climate change and human activities, the eco-environment of the Arctic region is endangered. Accelerated Arctic warming has endangered the survival of Arctic fauna. Rising temperatures have led to the migration of some Arctic species, and accelerated ice melt is also changing the Arctic food chains. Established Arctic marine species are being replaced by lower-latitude species, thus threatening birds and mammals that rely on sea ice as their habitats and breeding grounds. Global warming has led to extreme weather events in the Arctic region (Chang, J. & Guo, P., 2009; Sun, K. & Guo, P., 2008; Wang, G., He, J., Cai, M., Li, S., & Dai, C., 2005; Yao, H., 2012), further threatening the survival of the Arctic biosphere.

The Arctic has been the unfortunate recipient of radioactive, toxic, and acidic pollutants from other parts of the global ecosystem. These pollutants are brought into the Arctic by atmospheric circulation, ocean circulation, and ships crossing the Arctic passages. Given the increased level of human activities, including resource exploitation, processing, shipping, and travel in the Arctic region, air and ocean pollution are becoming increasingly serious threats. In turn, high concentrations of these pollutants through the biological chain will threaten the health of marine life, animals, and even humans (Guo, X., 2014; Yao, H., 2012). High levels of polychlorinated biphenyls have been found in the blood and fat of polar bears in Norway and Russia, and some polar bears, seals, and elephant seals have been found to suffer from molting and skin ulcers (Guo, X., 2014).

The attractiveness of the Arctic passages, combined with the abundance of Arctic resources, forms a positive feedback loop between the navigation of the passages and resource development. However, all these influences pose tremendous challenges for the fragile Arctic eco-environment.

3.2.1 Increased Environmental Pollution in the Arctic Region

The growing number of passing ships and the large-scale development of energy resources as a result of the opening of the Arctic passages will exacerbate both water and atmospheric pollution in the Arctic region. Such pollution typically comes from wastewater, waste gases, and solid waste emissions from shipping and natural resource development activities.

Leakage of oil and other substances is the primary contributor to Arctic pollution. This form of pollution is highly toxic and difficult to remedy. Such leakage is typically caused by mechanical malfunctions, collisions, stranding, and by oil and gas exploitation. As navigation capacity improves, the number of ships will increase, and as the scale of energy resource development expands, the frequency of leakages will increase. Wastewater and solid waste emission during ship passage will change the chemical composition of the seawater and result in pollution in the marine environment. Oil and other substances will be carried by the seawater and spread to other waters—across the globe—thus deteriorating the global marine environment. Moreover, ships will emit nitrogen and sulfur oxides into the air, which will react with water and oxygen already in the air to form acid rain, posing yet another hazard to the eco-environment.

3.2.2 Threatened Survival of Life in the Arctic region

The natural environment is the basis of all life. In addition to environmental disruptions, navigation of the Artic passages and the development of their resources will also pose serious threats to the survival of Arctic flora and fauna. Oil pollution, noise pollution, biological invasion, and facility construction are important threats in this regard.

As the Arctic ecosystem is only weakly self-regulating and is a low-temperature environment, oil decomposition and recovery are slower. As oil is toxic, buoyant, and adhesive, it will greatly endanger the survival of the Arctic biosphere. When coming into contact with fish and other marine species, oil can damage the nervous, respiratory, and reproductive systems, poisoning or even killing them. When floating on the water surface, oil will block solar radiation and prevent photosynthesis and will also reduce gas exchange between the air and seawater, thus affecting plant respiration. Oil may adhere to the feathers of birds or fur of animals, thus incapacitating or even killing them. Marine species such as whales, elephant seals, and sea lions—in addition to many species of fish—rely on sound for survival and reproduction; however, the low-frequency sound waves from shipping, oil and gas development and from icebreaking activities prevent such information exchange and communication.

Invasion of foreign species from discharged ballast water and bottom fouling is another important threat. Every day, as many as 3,000 types of marine animals and plants are spread throughout the world by ballast water (Hao, L., Shi, H., Wang, N., & Chen, K., 2005; Liu, F., Miu, J., Zheng, Z., & Wang, Y., 2007). These foreign species may compete with local species, thereby disrupting bio-diversity. Alternatively, foreign species may hybridize with the local species, thereby reducing local genetic diversity. Foreign species may carry pathogenic microorganisms with them during migration, leading to epidemics (Hao, L. et al., 2005). For the biologically unique, ecologically fragile Arctic, any biological invasion will likely mean fatal disruption. Development and construction of shipping facilities will also cause disruption to the local eco-environment, thus affecting the survival of the biosphere (Cao, Y., Liu, D., & Liu, J., 2011).

3.2.3 Intensified Climate Change in the Arctic region and Worldwide

The emission of greenhouse gases from ships will further exacerbate global climate change, affect global carbon circulation, and lead to a succession of other effects.

The Arctic waters, sub-Arctic waters, and the Arctic tundra are the world's most important carbon sink regions. Opening the Arctic passages will affect the region's carbon circulation both positively and negatively. In terms of gas emission and tundra melting, opening the passages will create a positive feedback loop with global climate change. Shipping will directly add to greenhouse gas emissions in the region, whereas tundra melting will release large quantities of methane, thus accelerating global warming, as greenhouse forcing by methane gas is 20 times that of CO2. With regard to sea ice melting, a reduction of the sea ice coverage area may increase carbon absorption by the ocean, thereby allowing carbon to be transported to the seafloor in the form of particles, which will mitigate carbon emissions and create a negative feedback loop (Cao, Y. et al., 2011; Chen, L., Gao, Z., Yang, X., & Zhan, L., 2004; Gao, Z. & Chen, L., 2007).

Climate change has led to a succession of other environmental effects. The Arctic glacier is one of the two largest solid freshwater reservoirs on earth, accounting for 70% of the world's total freshwater reservoirs. Once the glacier has melted, the earth's freshwater resources will face severe challenges (Li, P., 1996). Dynamic changes in the Arctic ecosystem will also trigger eco-environmental changes in other parts of the world. Climate change in the Arctic will increase the frequency of extreme weather events and natural disasters—such as storm surge—in other areas.

3.2.4 Changes in the Production and Lives of Arctic Residents

Humans are a part of the ecosystem. In navigating the Arctic passages and developing Arctic resources, humans are both active participants and victims. Specifically, the lives of the Arctic region's indigenous residents (such as

the Inuit and related groups) will be particularly affected.

Atmospheric pollution and water pollution resulting from navigating the Arctic passages could lead to an outbreak of diseases that threaten the health of Arctic natives. Increased airborne CO and NOx will greatly affect the oxygen carrying capacity of the human body. If NO2 finds its way into the human lungs, it can form nitrous and nitric acid, which increase the permeability of the capillary vessels and consequently cause distress, coughing, asthma, and even emphysema (Mao, Y., Ren, W., Lu, Z., & Luo, S., 2007). Water pollution can severely affect the safety of drinking water. The Arctic's indigenous residents have traditionally made their living from farming, animal husbandry, fishing, hunting, and collecting and processing animal furs. Their food sources are mainly fish, reindeer, whales, seals, and birds (Zhang, M., 2013). Opening the passages will not only constitute a threat to these residents' survival but also indirectly affect their lifestyles. The reduction of fauna will reduce their incomes. Changes in the food chain will affect their dietary and cultural habits.

3.3 Comprehensive Analysis of Positive and Negative Effects Based on System Dynamics

An analysis of the resource and environmental impact of the Arctic passage shows that the use of the Arctic passages will have a positive effect on global trade and economic development as well as a negative impact on the Arctic system[s ecosystem. The paper utilizes a system dynamics model to further analyze the interaction between Arctic Passages Navigation and the Arctic Resources and Environment to ensure sustainable development.

System dynamics theory was established by Forrest (J.W. Forrester) in 1956 at the Massachusetts Institute of Technology (MIT), and it made important advances on the basis of a hypothetical. System dynamics is a method of simulating a causal relationship, in which the structure of the system is clearly shown as a causal graph: if event A causes event B (results), the two will form a causal relationship if the change in A caused by the same change in B is said to constitute a positive causal relationship with regard to A and B, and vice versa.

In this system, we set the stability of the international order, the national economic development level, ecological environment pollution and damage degree, and gas emissions as the terminal of the model (Figure 4). Four positive effects routes and 6 negative effects routes are connected to the terminal via this flowchart. One result of the positive effect routes is to improve the level of national economic development using 2 paths primarily: one approach is via the navigation of the passage, which will facilitate the development of Arctic resources and ease the global energy crisis, thus promoting economic and social development; the other approach considers the Arctic passages as new trade channels that promote global trade, reduces pressure on traditional channels, and ultimately contributes to the region's economic development. Another positive result might be achieved by improving environmental pollution control and reducing environmental pollution by increasing scientific research capabilities The negative effects include reduced international stability as well as increased pollution and destruction in the Arctic region's natural environment by 3 means. First, increased emissions caused by high levels of resource development will exacerbate environmental damage and pollution. Second, a higher volume of emissions from more shipping vessels in the region will lead to an increase in environmental pollution levels, which will further hasten climate change. Finally, global competition for Arctic resources and the Arctic passage itself will seriously affect the stability of the international order. In addition, increased navigation will yield both positive and negative effects regarding the amount of sea ice and thawing permafrost, which are quantitative results of global warming (Figure 4).

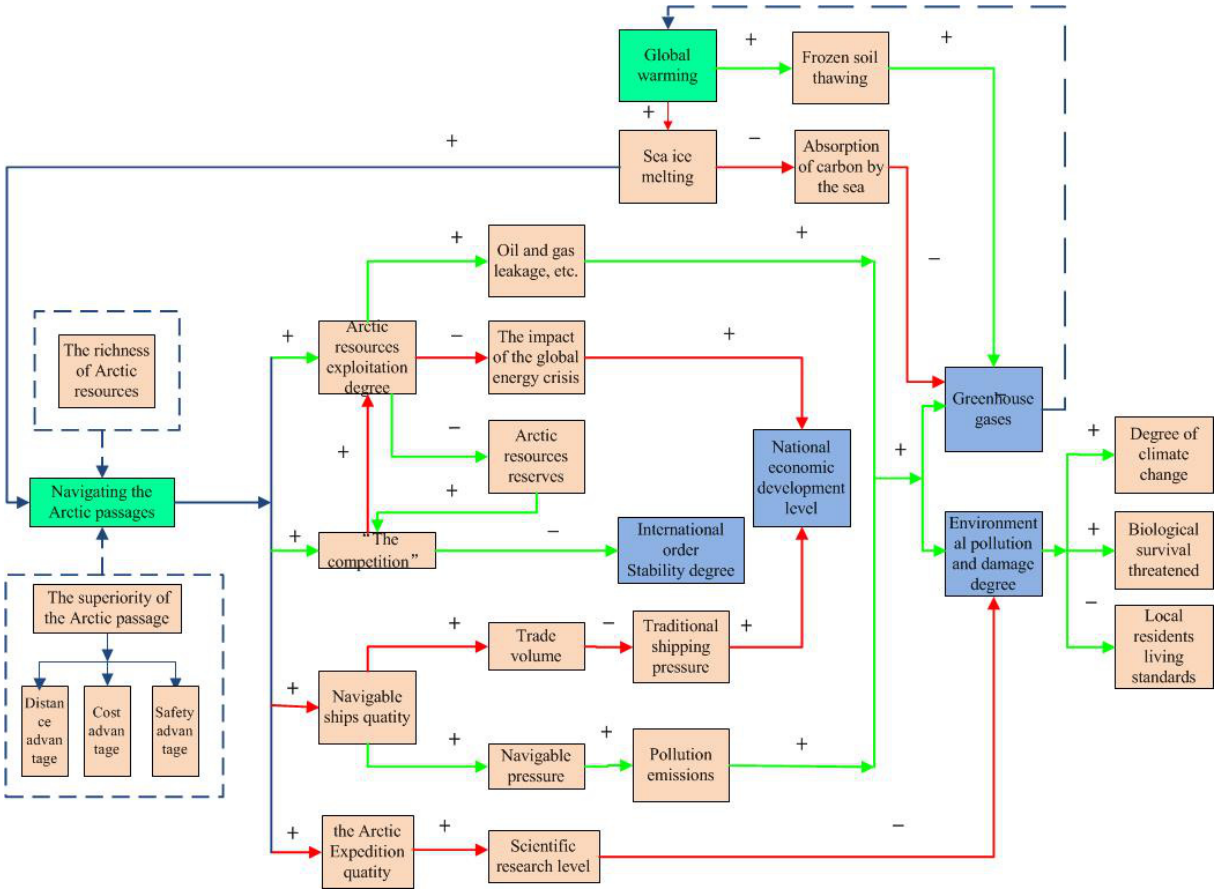

Figure 4. The positive and negative effects of the navigation of the Arctic Passages

4. Sustainability Measures of Arctic Navigation and the Arctic Resources and Environment

After the Arctic passages are opened, reconciling resource development with eco-environmental protection will become an important challenge. To ensure the sustainability of the Arctic passages and the Artic region overall, we propose the following measures.

4.1 Enact Ecological Legislation and Establish an Administrative Mechanism for the Arctic Passages

There is no international legal framework regulating the eco-management of the Arctic. Existing rules only involve global eco-environmental issues. It is imperative that the international community and the countries that are directly affected establish a legislative system to regulate the eco-environment of the Arctic passages, to agree on a shipping management and environmental protection policy that clearly defines emissions and noise pollution standards for ships, to develop an Arctic passage management mechanism targeted at ecosystem management, and to set up a special shipping management organization to regulate shipping traffic.

4.2 Limit Development of Arctic Resources and Protect the Arctic Eco-Environment

The international community must actively research the energy resources and eco-environment in the Arctic region to fully understand the resource potential, environmental conditions, and passage status. Development of Arctic resources must take local conditions into account. Nature reserves should be established in special areas as part of a scientific management system that addresses both resource exploitation and ecosystem preservation. Environmental pollution-monitoring and prevention mechanisms must be refined, and a rational monitoring and prevention system must be established to improve the emergency response capacity and to minimize or prevent the environmental effects resulting from transport and resource development.

4.3 Increase Scientific Research and Improve Environmental Protection

Further scientific investigation of the Arctic is required, including advanced environmental impact assessments to reconcile resource development and environmental protection. Research and development (R&D) in oil and other energy development equipment will play an important role in reducing the environmental impact of

development activities. Technical innovation is required in shipbuilding, waste emission, noise pollution reduction, and technological support for protecting the Arctic environment. R&D for emergency responses to oil spills can help minimize pollution events in Arctic waters.

4.4 Strengthen International Cooperation and Achieve Sustainable Development

Navigating the Arctic passages while protecting the eco-environment and achieving sustainability in the Arctic region requires a global effort. Intensifying technical cooperation with respect to shipping infrastructure construction, shipbuilding, and energy development among the involved countries is important. Cooperation between countries and international organizations is necessary to establish international standards to manage the navigation of the Arctic passages and the eco-environmental protection of the Arctic. In addition, greater cooperation will be required between Arctic and non-Arctic nations to ensure the peaceful, stable, and sustainable development of the Arctic region.

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