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The Potential Effects of Climate Change on Arctic Ocean Navigation and Its Implications for Taiwan's Socio-Economic Society: An International Law Perspective

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study explores the potential effects of climate change on Arctic navigation and its implications for Taiwan's socio-economic fabric, through an international legal lens that considers geographical, socio-economic, and global political factors. The research review followed the methodological framework established by the Joanna Briggs Institute (2015) and drew upon Arksey and O'Malley's (2005) approach for summarizing and disseminating research findings, while adhering to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The ongoing effects of climate change and global warming have accelerated glacial melting, easing access to Arctic waters and opening new shipping routes, such as the Northeast Passage and Northwest

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Passage, which have notably impacted Taiwan's socio-economic dynamics. Climate change significantly affects ocean-based economies, as it shapes oceanic processes, which in turn directly influence social and economic activities.

Keywords: Climate change; arctic ocean; navigation; international law; Taiwan.

1. INTRODUCTION

In recent decades, there has been an unprecedented global increase in interest in the Arctic Ocean attributable to the effects of climate change and the new emerging economic possibilities caused by global warming. Geographically, the Arctic Ocean plays a crucial role in balancing the global climate by acting as the top-based reflector of the sun's rays into space, which maintains global temperatures. From a socio-economic perspective, the Arctic Ocean directly affects the lives of billions of people who rely upon its navigation routes for economic and social activities (Quillérou et al., 2020; Tiller et al., 2022). The blue economies and coastal communities use the Arctic ocean for commercial activities such as fishing, transportation, and extraction of minerals and hydrocarbon (Huntington et al., 2022). Also, the ocean is a primary navigational route that occupies a critical position in global maritime trade, and is used for delivery of supplies such as fuel, construction materials, non-perishable food and other tradable items between different countries and communities (Chen & Liu, 2022; Huntington et al., 2022; Alvarez et al., 2020). Before the modern technological civilization, the Arctic social interactions were limited by geography and were mostly covered by ice and characterized by physical contours and environment that did not allow habitation, exploration, navigation and mining (Norchi & Lynch, 2022). However, anthropogenic climate change is transforming the geography of the ocean which is affecting its navigational routes and the socio-economic aspects of surrounding blue economies such as Taiwan (Freestone & Çiçek, 2021).

An understanding of the possible impacts of climate change on the Arctic Ocean navigation on Taiwan's society requires an in-depth understanding of the associated geographical, socio-economic, legal and global political factors. According to a blue paper by Gaines et al (2019), anthropogenic climate change is caused by the exponential growth in emissions of green-house gases (GHCs) which has been witnessed during the industrial revolution period and the effects of the phenomenon has resulted to changes in ocean processes and functioning which had had far-reaching implications on the global economy. The direct consequences of climate change could have a disruptive effect on the natural order of the Arctic ocean and the related socio-economic activities with the dwindling sea ice opening up new operational navigation routes (Norchi & Lynch, 2022; Gössling et al., 2023). The rise in the sea levels is a crucial signal of the effects of climate change and it has become a critical area of international law concern due to the shifting of the maritime boundaries and zones, disappearance of Island states, flooding of low-lying coastal states and even possible reassigning of populations (Norchi & Lynch, 2022; Sorokina, 2024). As a blue economy reliant on the Arctic Ocean, Taiwan is expected to feel the effects of climate change on the Arctic Ocean navigation on its socio-economic society considering the country uses maritime transportation as a key means for transportation of cargo and participation in international trade (Brigham, 2022; Rowe, 2020).

The Asia and the Pacific region, which includes Taiwan, is becoming increasingly vulnerable to the fast-coming effects of climate change on the Arctic Ocean. Currently, the Arctic temperatures are increasing twice as fast as the global average with studies even suggesting that the Arctic might be ice-free in the next two decades (Carvalho, & Wang 2020; Chen & Liu, 2022; Diebold & Rudebusch, 2022; Langlet, 2022). The continued effects of climate change and global warming has exacerbated glacial melting which has made it easier for ships to access the Arctic waters and further opened navigational routes that offers reduced transit times (Chen et al., 2023; Sarojini Suma et al., 2024). Based on its strategic location in international trade routes, the opening of the new navigation routes across the Arctic ocean is expected to have a significant impact on Taiwanese trade balances largely due to the exceedingly high demand for maritime global trade (Chen & Liu, 2022; Li & Lynch, 2023). In 2021, Taiwan reported increased trade volumes with Europe and the United States with container ships across the Arctic ocean accounting for the highest proportion of the country's total import and export volumes (Chen & Liu, 2020; Lukin, 2020). While Taiwan plays a

critical role in the global maritime trade across the Arctic ocean, the research on the role of effects of climate change on the socio-economic aspects of the country in relation to changes in the navigation routes is lacking (Martins, 2023). The current research study focuses on investigating the possible impacts of climate change on Arctic navigation on Taiwan's socio-economic society by providing an international legal perspective of the geographical, socio-economic, and global political factors.

2. LITERATURE REVIEW

With the Arctic ocean opening up new shipping and navigation routes, there has been an increased interest on research associated with the effects of climate change on oceanic processes and changes, and their foreseeable impact on socio-economic activities of the related economies. However, most of the research studies have adopted a wider scope of a global perspective by focusing on the global effects of climate change. Also, some of the studies have focused on the political tensions and relationships between the major economic powers that have a major stake in the Arctic Ocean such as Russia and China. As a result, only a few research studies have provided a detailed analysis of the changes of the socio-economic order of smaller countries such as Taiwan, that are associated to the effects of climate change on Arctic navigation. While specific literature on the topic of the research might be lacking, there is a rich volume of primary and secondary literature that have focused on the effects of global change on the Arctic ocean processes and changes that might have a spiral effect on the associated economies. To this end, the current literature review incorporates a wide range of sources to provide an international legal perspective of the effects of climate change on Arctic navigation with a focus on understanding the related changes of the socio-economic order of Taiwan.

Mendenhall et al. (2020) conducted a research study on the impact of climate change on the ocean environment with a focus on navigational fishing routes. According to Mendenhall et al. (2020), global climate change is likely to increase the risk of fisheries conflicts between blue economies due to the opening up of unclaimed navigational fishing routes caused by warmer waters, ocean acidification and rise in sea levels. The study points to the fact that global climate change has direct and indirect consequences on marine ecosystems and resources as well as societies that depend on the oceans for income, food and cultural value (Mendenhall et al., 2020). It is reported that climate change is directly altering the locations and navigational routes of access to fish which leads to an overall prevalence of fisheries disputes among communities and international economies leading to constant changes of international laws that define the governance of fisheries locations across the oceans (Mendenhall et al., 2020). Also, global warming affects fish populations in oceanic environments through shifts in species distribution that fuels multiscale spatiotemporal changes in fish stocks and their access (Mendenhall et al., 2020). As a result, the existing navigational fishing routes either lack fish or new routes are created to access the shifting fish populations (Mendenhall et al., 2020). Based on the study findings, it can be reported the changing navigational routes and the shifting of the fish populations attributed to Arctic ocean changes increases the likeliness of fisheries conflict between communities along the coastal shores of the ocean.

A study by Zou (2021) investigated the implications of international law on management of ocean routes with a focus on the effects of climate change. In the research, Zou (2021) reports that the rising sea levels attributed to climate change can destroy the existing coastal ecosystems and ocean composition which are essential for maintaining oceanic life. Also, the author reports that climate change directly affects fisheries and the fishing industry in East Asia and, consequently, affects the socio-economic aspects of the livelihoods of the involved communities (Zou, 2021). In the context of international law, Zou (2021) highlights the significance of United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention on the Law of the Sea (LOSC), which were formulated to provide the legal framework for governance of climate change and oceans. While the two set of laws are governed by different regimes, they share common legal principles such as the principle of sustainable development, ecosystem approach and pre-cautionary principle (Zou, 2021). Another important international law related to climate change and the Arctic ocean is the Seabed Chamber of the International Tribunal for the Law of the Sea (ITLOS) which is based on an international judicial system and advocates for a pre-cautionary approach when dealing with ocean activities (Zou, 2021). The formulation of

the international laws to govern oceans account for the effects of climate change by outlining legal principles to address the issues arising from changes in ocean processes and composition that can disrupt the existing socio-economic and political order in countries such as Taiwan.

Chen & Liu (2022) conducted an environmental and economic analysis on sailing from Taiwan through the Arctic passages. The findings show that the continued effects of climate change and global warming has increased glacial melting which has made it easier for ships to access the Arctic waters and further opened navigational routes (Chen & Liu, 2022). Specifically, the effect of global warming has opened up two new navigation channels for arctic passages, the Northeast Passage and Northwest Passage, which have had significant impacts on socio-economic aspects of the Taiwanese society. Chen & Liu (2022) report that the opening of the new navigation routes across the Arctic ocean is expected to have a significant impact on Taiwanese trade balances largely due to the exceedingly high demand for maritime global trade and its strategic location in the international maritime trade routes. According to the analysis, the cost of sailing through the new navigational routes created by melting of the Arctic Ocean ice costs less than does sailing a typical container ship along the Europe sea route without tolls (Chen & Liu, 2022). Also, study observed that a slight increase in the sailing speed through the Northeast passage would significantly reduce the cost of travelling as compared to the conventional navigation routes such as the Europe sea rate. The findings by Chen & Liu (2022) highlight the impact of climate change on Arctic navigational routes and on the socio-economic aspects of the Taiwanese society.

A wide range of research studies have investigated the impacts of climate change on the Arctic passageways from an international dimension, and the possible impacts on the societies of the blue economies including Taiwan. Briones-Peñalver et al. (2023) conducted a research study on the effects of climate change on the strategic vectors of coastal tourism development as a blue economy component in the international dimension by focusing on socio-economic activities such as fisheries, shipping, tourism (beach and cruise), transportation and logistics. Carvalho & Wang (2020) investigated the patterns and mechanisms of changes of sea surface temperature in the Arctic Ocean and its marginal seas in the changing climate, and the possible effects on the surrounding communities. Crépin et al. (2017) provided integrated perspectives on the relationships between arctic climate change, economy and society while Chen et al. (2023) provided the perspective of ship fuel costs and carbon emissions on arctic route planning and navigation strategies. Gaines et al. (2019) wrote a blue paper on the expected impacts of climate change on ocean economy focusing on the impacts of the changes on the related socio-economic activities such as finishing, coastal tourism and navigational routes across the ocean. Norchi & lynch (2022) investigated the relationship between Arctic navigation and climate change, and the potential impacts on the coastal communities using projections from science for the Law of the Sea. Overall, the studies confirm that the changing climate affects the Arctic navigation and the socio-economic activities of the coastal communities in blue economies such as Taiwan.

3. METHODOLOGY

The current research review focuses on the possible impacts of climate change on the Arctic navigational routes and the subsequent effect on the socio-economic activities of the Taiwanese society. It provides a detailed empirical analysis of existing literature on the changes on the processes and composition of the Arctic ocean that has changed the initial navigational routes and how these changes have affected the Taiwanese communities. To achieve the research objectives, the review incorporated a wide range of sources and, therefore, adopted the qualitative policy analytical research methodology of analysis of existing perspectives of policies associated with climate change, Arctic navigation, international law and the socio-economic changes in Taiwan attributed to these changes. The qualitative policy analysis methodology is most appropriate for the research paper due to the ability to manage the practicability of the unmanageable public policy and available academic literature recommendations. To effectively synthesise and analyze the existing academic literature, the review adopted the methodological framework outlined by the Joanna Briggs Institute (2015) and was informed by Arksey and O'Malley's (2005) approach of summary and dissemination of research findings and, in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)

guidelines. The different sources of the materials included bibliographic databases containing journals, government documents, think-tank statistics patents, as well as the sources of cited references to provide detailed information on the topic of research.

The identification of research materials to be incorporated in the review followed the methodological framework by Kraus et al. (2020). The three-step strategy by the framework was used for identification of the relevant research terms and phrases for the studies to be included and the materials selected were based on on their reliability and literature quality. The first step involved the formulation of an inclusion and exclusion criteria that was used to choose the relevant material sources for achievement of the review objectives. The materials included in the review included those that focused on the effects of climate change on oceans and the surrounding communities in blue economies such as Taiwan. The second step of the framework entailed the detailed analysis of the policy and sustainability perspectives associated with curbing climate change and addressing the possible negative impacts of the phenomenon on the Artic Ocean while taking into consideration the possible positive impacts including the opening up of oceanic pathways. The second step was guided by was guided by a preliminary review of the existing policy and sustainability perspectives on the topic based on relevant research terms and phrases of the included materials. It is important to note that the review incorporated studies with a regional and global scope considering it was based on an international legal perspective and the global impact of climate change. Any possible informational source that was related to the topic of interest but could not be identified based on the search strategy was incorporated on the basis of cross-referencing and hand searches of the reference lists of the included studies and the existing systematic reviews and meta-analyses on the topic.

Climate Change impact on the Arctic navigation and socioeconomic in Taiwan: Climate change has significantly impacted Arctic navigation, primarily through reducing sea ice, leading to increased accessibility of Arctic shipping routes. Key statistics illustrating these changes include the decline of the Sea Ice. The observed decline in Arctic sea ice due to climate change is both rapid and severe, with substantial impacts on global and regional ecosystems (Madani et al., 2023; Sorokina, 2024; Suma et al., 2024). Satellite data spanning the past four decades reveals a steady decline in Arctic sea ice extent and thickness. This decline is most pronounced in summer, with an estimated annual loss rate of 4.3% in sea ice extent from 1979 to the present (Cocetta et al., 2024). Additionally, the thickness of Arctic sea ice has been decreasing consistently, reducing total ice volume. Recent data from Bocqu et et al. (2024) shows that this reduction is evident across all months, contributing significantly to the overall variability in sea ice volume and demonstrating the sensitivity of Arctic ice to warming temperatures. The implications of this loss are far-reaching. Arctic sea ice plays a crucial role in regulating the Earth's climate by reflecting sunlight; as it diminishes, more heat is absorbed by the ocean, amplifying global warming. Furthermore, studies by Dong et al. (2024) highlight how the reduction in sea ice affects mid-latitude weather patterns, including colder winters in parts of Eurasia, due to shifts in atmospheric circulation driven by Arctic warming.

Predictions suggest that without substantially reducing greenhouse gas emissions, the Arctic could experience ice-free summers by the 2030s to 2050s (Bocquet et al., 2024). This shift will have significant ecological impacts, altering habitats for species dependent on sea ice, such as polar bears and seals, and leading to more frequent extreme weather events globally. On the other hand, there is public concern about the impact of climate change on marine biodiversity and the marine industry. Changes in the Arctic ecosystem may affect fish populations, which in turn may affect Taiwan's fishing industry. Taiwan's fishing industry may face changes in fish supply, affecting both the domestic market and the export industry (Sibul et al., 2021). As warming Arctic waters influence fish migration, commercially valuable species could shift, for instance, driving warm-water species northward and reducing populations of cold-water species, which disrupts traditional fishing patterns and decreases Taiwan's domestic fish catch stability, impacting Taiwan's fishing industry, which is a vital part of its economy and cultural identity. Access to new fishing grounds could diversify and expand Taiwan's seafood supply, potentially enhancing food security and opening export markets for Arctic-sourced seafood (Sibul et al., 2021; Ho et al., 2016).

The impact of climate change on the Arctic navigation route is conceptually relatively far

away due to its geographical location, but, in reality, the impact on Taiwan's social and economic activities can be found in the benefits in areas such as energy security, environmental research, fisheries, and tourism, in addition to trade. Regarding navigation and environmental conservation, the researcher highlights that Arctic routes can reduce CO_2 emissions by 3-7%, supporting global emission reduction goals (Chen et al., 2023). However, the authors suggest that lowering ice-breaking fees or increasing transit speed could make these routes more economically viable for Taiwan's shipping industry. The study concludes that while Arctic routes offer environmental benefits and shorter travel times, their current cost structure limits widespread commercial use. Using the Northern Sea Route (NSR) can cut travel time between East Asia and Europe by up to 30-40%, significantly reducing shipping costs (Liu et al., 2010). For Taiwan, this can mean cheaper transportation for exported goods, enhancing Taiwan's trade competitiveness. Meanwhile, lower transit costs can make Taiwan products more competitive in European markets, potentially boosting export revenues and fostering economic growth (Bekkers et al., 2016). For the Opportunities for Energy and Raw Material Imports, Taiwan could explore investments in Arctic port infrastructure, strengthening trade links and creating long-term economic ties with Arctic nations, thereby securing energy resources vital for Taiwan's industrial sectors (Lasserre, 2015). Meanwhile, Arctic shipping can lead to ecological issues, such as oil spills, ice melting, and pollution, which affect the marine environment on a global scale. Taiwan may need to adhere to international environmental standards, adding compliance costs to ensure its shipping practices align with the regulations set by organizations like the International Maritime Organization (IMO) (Lasserre, 2015). In addition, although Taiwan is not a signatory to certain international conventions, it may still face indirect regulatory obligations to maintain access to the Arctic shipping route.

4. FINDINGS

The methodological search strategy of the review yielded a total of 102 sources including policy papers, white papers, government documents and academic literature associated with the effects of climate change on the Arctic Ocean (and related water bodies), and the impacts of the changes on the socio-economic aspects of the Taiwanese community (and related blue economies). The different article sources included journals such as *Marine Policy and Educational Handbook, Sustainability,* and *Ocean and Coastal Management.* Other materials sources included *Marine Policy and Educational Handbook, Journal of Marine Science and Technology, Marine Science and Engineering, and Energy and Environment.* After the removal of the duplicated articles, a total of 64 articles remained, of which 35 did not meet the inclusion criteria and, therefore, only 31 were obtained for detailed eligibility assessment. Further, eight studies did not meet the eligibility criteria and were excluded from the final list of the studies included in the review and a total of 23 full-text articles were eligible for inclusion in the review. The detailed and comprehensive analysis of the most applicable research findings are provided in Table 1.

Table 1. Detailed and comprehensive analysis of the most applicable research findings

No	Author	Year of Publication	Findings
1	Briones-Peñalver et al.	2023	Blue economies are reliant on ocean for different socio-economic activities and any possible changes can affect the existing societal order.
2	Carvalho & Wang	2020	Sea surface temperature variability in the Arctic Ocean and its marginal seas in a changing climate has a significant impact on the socio-economic activities on the surrounding communities.
3	Chen et al.	2023	The alternative Arctic shipping navigation routes produced as a result of global climate change require short transit times and incur lower fuel costs as compared to the conventional navigation routes.
4	Chen & Liu	2023	The continued effects of climate change and global warming has increased glacial melting which has made it easier for ships to access the Arctic waters and further opened navigational routes; the Northeast Passage and Northwest Passage, which have had significant impacts on socio-economic aspects of the Taiwanese society.

No	Author	Year of Publication	Findings
5	Diebold & Rudebusch.	2022	The Arctic temperatures are increasing twice as fast as the global average and the Arctic might be ice-free in the next two decades.
6	Gaines et al.	2019	Climate change has a significant impact on ocean economies as it determines the changes and processes of oceans which directly influences the social and economic activities such as ocean transport, tourism and fishing.
7	Gosling et al.	2023	Climate change has a significant impact on water transportation systems and defines the navigable routes in water bodies.
8	Huntington et al.	2022	The blue economies and coastal communities use the Arctic ocean for commercial activities such as fishing, transportation, and extraction of minerals and hydrocarbon, and any possible changes have a significant impact on the existing social and economic order.
9	Martins	2023	Changes in the Arctic Ocean due to the global climate change has created international political tensions that has necessitated the formulation of international laws for regulation of associated socio-economic activities in the blue economies.
10	Mendenhall et al.	2020	Climate change is directly altering the locations and navigational routes of access to fish which leads to an overall prevalence of fisheries disputes among communities and international economies leading to constant changes of international laws that define the governance of fisheries locations across the oceans.
11	Norchi & Lynch	2022	The rise in the sea levels is a crucial signal of the effects of climate change and it has become a critical area of international law concern due to the shifting of the maritime boundaries and zones, disappearance of Island states, flooding of low-lying coastal states, which requires international legal interventions to address.
12	Westerveld	2020	Climate change has a significant impact on maritime boundaries and exclusive economic zones, and affects the socio-economic activities of societies within the boundaries.
13	Zou	2021	The study highlights the significance of the significance of United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention on the Law of the Sea (LOSC), which were formulated to provide the legal framework for governance of climate change and oceans.

5. DISCUSSION

The review findings clearly indicate significant impacts of climate change on the Arctic navigational routes and the subsequent effects on the socio-economic aspects of the surrounding economies including Taiwan. According to the findings, the recent changes in the Arctic Ocean has garnered significant international interest since the formulation of the United Nations Convention on the Law of the Sea (UNCLOS) in 1994 as a result of the consequences of global warming and the new possibilities that are opening up due to the subsequent changes attributed to climate change. The findings show that climate change has created new possibilities in the Arctic Ocean including increased access to resources that were previously unknown to human beings as well as the opening up of new navigational routes across the ocean. The Arctic temperatures are increasing twice as fast as the global average and it has been suggested that the Arctic might be ice-free in the next two decades, a finding which is expected to have significant impacts on the socio-economic activities of blue economies such as Taiwan. The continued effects of climate change and global warming has exacerbated glacial melting which has made it easier for ships to access the Arctic waters and further opened navigational routes including the Northeast Passage and Northwest Passage, which have had significant impacts on socio-economic aspects of the Taiwanese society by improving tourism activities, fishing, navigation and related oceanic activities. The findings show that climate change has a significant impact on Arctic navigational routes and the socio-economic aspects of the Taiwanese society.

The international legal perspective of the governance of oceans with consideration to the effects of climate change are based on specific legal regimes and laws including the United Nations Framework Convention on Climate Change (UNFCCC) and the United Nations Convention on the Law of the Sea (LOSC), which were formulated to provide the legal framework

for governance of climate change and oceans. According to the research findings, the associated legal regimes are based on more or less similar principles including the principle of sustainable development, ecosystem approach and pre-cautionary principle. Also, the Seabed Chamber of the International Tribunal for the Law of the Sea (ITLOS) is another legal framework for ocean and climate change governance that is based on an international judicial system and advocates for a pre-cautionary approach when dealing with ocean activities to address any existing issues that might arise from the effects of climate change on the surrounding socio-economic activities of the affected economies. The findings show that the Arctic sea ice is rapidly decreasing and the massive transition to a possible iceless Arctic ocean has raided economic expectations on the economic viability of the new navigational routes in the very near term which is expected to directly affect the socio-economic activities of the related economies including Taiwan. Most certainly, it is expected that the changes shall have significant impacts on the Taiwanese economy but it is important to note the impact of the changes on the overall global climatic condition, which might include extreme temperature changes in other parts of the globe.

The research further highlights the existing uncertainties and complexities of the drivers of change that influence the future of the Arctic ocean operations and, specifically, oceanic shipping. According to the findings, the Arctic Ocean is becoming more navigable and there is an increased access to marine areas that had never been access before, with possibilities of longer seasons of marine navigation during spring, summer, and autumn, even though there is a possibility of alteration of global trade routes. The findings show that the Arctic ocean remains largely destinational, especially with ships traveling through Arctic Ocean to partake in economic activities. Based on the findings, it is recommended that there should be a holistic and high-level view of international laws and regulations for evaluation of the future Arctic marine use determine the plausibility of future destinational and trans-Arctic voyages. In this endeavor, there are three influential drivers to a better understanding of this future, especially for a blue economy such as Taiwan. First, it is important to consider the economic viability and pace of Arctic natural resource developments and their relationships with the global laws, commodity pricing and markets. Second, it is important to take into account the complex economics and the wide range of stakeholders within the global shipping enterprise. Lastly, it is important to consider international governance and Arctic national regulations for ship operations throughout the Arctic Ocean. The necessary and appropriate regulations include the United Nations Convention on the Law of the Sea, UNCLOS, as the primary legal framework for the Arctic Ocean and the International Maritime Organization's mandatory rules and regulations for ships operating in polar waters (the IMO Polar Code).

6. CONCLUSION

The research focused on the possible impacts of climate change on the Arctic navigational routes and the subsequent effect on the socio-economic activities of the Taiwanese society. An understanding of the possible impacts of climate change on the Arctic Ocean navigation on Taiwan's society is important in understanding its disruptive effect on the natural order of the Arctic ocean and the related socio-economic activities with the dwindling sea ice opening up new operational navigation routes. Based on its strategic location in international trade routes, the opening of the new navigation routes across the Arctic ocean is expected to have a significant impact on Taiwanese trade balances largely due to the exceedingly high demand for maritime global trade. The findings further highlight the necessity of considering the economic viability and pace of Arctic natural resource developments and their relationships with the global laws, commodity pricing and markets. Lastly, it is important to consider the international governance and Arctic national regulations for ship operations throughout the Arctic Ocean and the necessity of undertaking a holistic and high-level view of international laws and regulations for evaluation of the future Arctic marine use determine the plausibility of future destinational and trans-Arctic voyages.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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