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Impacts of Using the Northern Sea Route on the Macroeconomy and on Liquefied Natural Gas Import Diversification in Japan

Takashi Usami
Department of Civil Engineering, The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
Phone: +81-3-5841-7451; Fax: +81-3-5841-7496
E-mail: usami-t@ip.civil.t.u-tokyo.ac.jp

Hironori Kato (corresponding author)
Department of Civil Engineering, The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, Japan
Phone: +81-3-5841-7451; Fax: +81-3-5841-7496
E-mail: kato@civil.t.u-tokyo.ac.jp

Ryuichi Shibasaki
Head of International Coordination Division
National Institute for Land and Infrastructure Management (NILIM)
Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan
1-12 Shinmei-cho, Yokosuka, Kanagawa, 239-0832, Japan
Phone: +81-46-834-9584; Fax: +81-46-834-9843
E-mail: shibasaki-r92y2@mlit.go.jp

ABSTRACT

This study investigates the economic feasibility of trading liquefied natural gas (LNG) via the Northern Sea Route (NSR) and examines the potential impacts on the regional macroeconomy and LNG import diversification, particularly in Japan. First, 19 future scenarios are developed incorporating three uncertain factors, namely the bunker fuel price and oil price, Russian ruble–US dollar exchange rate, and Arctic sea ice extent, derived from face-to-face interviews with experts in Russia in 2014. Next, the LNG shipping costs between Northwest Europe and East Asia are compared for the NSR and another sea route (i.e., the Suez Canal route) to assess the economic feasibility of using the former. Then, the expected economic impact is estimated by using the Global Trade Analysis Project model, a computable spatial general equilibrium model, and estimated trade costs. Exogenous factors that may influence the future economic balance—such as sociodemographic factors, the tariff rate among countries, natural resource development, and the transportation cost reduction rate—are investigated. The main findings are (1) LNG shipping trade via the NSR could be economically feasible for Japan; (2) the use of the NSR contributes to Japan's macroeconomy but has a relatively small effect; and (3) the use of the NSR significantly contributes to diversifying the LNG import portfolio. These results imply that Japan could benefit from using the NSR and should thus encourage its future use.

Keywords: The Northern Sea Route, liquefied natural gas, scenario analysis, cost analysis, economic impact analysis

INTRODUCTION

The Arctic sea ice extent has been decreasing as a result of global warming, at a rate of 9.4% to 13.6% per decade for the summer sea ice minimum (*1*). In addition to this environmental effect, global warming has produced another notable consequence: the opening of the Northern Sea Route (NSR), which connects Northwest Europe with Northeast Asia via the Arctic Ocean. Transits via the NSR have increased from four in 2010 to 71 in 2013, and 31 in 2014, where liquid bulk accounts for half of the freight carried (*2*). Consequently, a number of researchers have forecast that the volume of liquefied natural gas (LNG) trade using the NSR will increase rapidly in the future. In the context of Japan, this expected increase in LNG trade via the NSR would help meet growing domestic demand for LNG. The country's nuclear power supply has almost stopped since the devastating effects of the Great East Japan Earthquake and subsequent tsunami on the Fukushima nuclear power stations in March 2011, which raised people's awareness about the danger of nuclear power stations, and this has promoted a drastic shift in energy resources from nuclear to others including LNG. However, few studies have investigated the large potential impact of using the NSR for LNG trade, particularly to Japan, the world largest LNG importing country as of 2014.

This study forecasts the future trade patterns of LNG under multiple scenarios to analyze the potential impacts on Japan's macroeconomy and discusses policy implications. It develops 19 scenarios reflecting uncertain factors in the future and assesses their cost performance and economic impacts. This study has three unique challenges compared with existing research. The first challenge is to introduce the latest tariff system of the NSR, which was stipulated by the Russian government in March 2014. To the best of the authors' knowledge, this new charging system has not been examined in other studies. The second challenge is to incorporate seasonal variations when estimating the trade cost. This is because the changes in the Arctic sea ice extent dynamically depend on the season. Although many studies estimate the trade cost in the NSR, few take seasonal changes into account. The third is to evaluate the impacts of using the NSR under many scenarios. Although some studies such as Francois and Rojas-Romagosa (*3*) have also investigated the economic impact of using the NSR by estimating the transportation cost using a regression-based gravity model, they analyzed it under a single scenario only. This study sets up its scenarios following a method presented by Royal Dutch Shell (*4*), a pioneering strategic approach to developing scenarios.

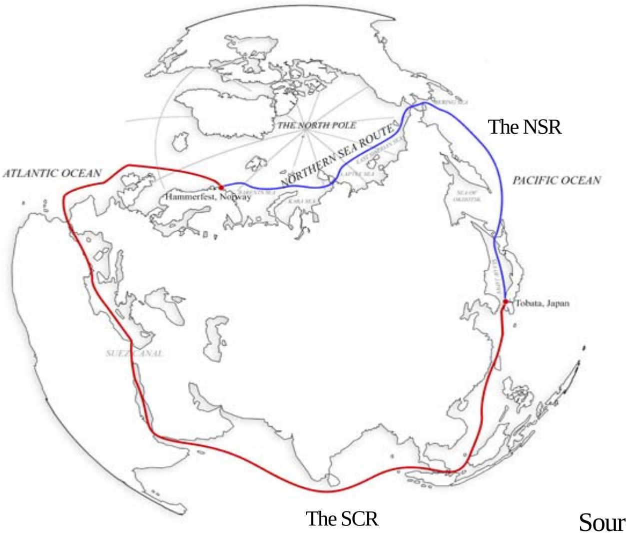
The remainder of this paper is organized as follows. The next section briefly describes the history and current situation of the NSR and then develops the scenarios. Then, this paper presents the maritime transportation cost and economic impact analyses and discusses policy implications. Finally, the findings are summarized and further issues noted.

THE NSR

The NSR is one of the sea routes that pass through the Arctic Ocean, as shown in FIGURE 1. It is defined as a coastal route of Russia, between the Kara Strait—the strait between the continent and the Novaya Zemlya archipelago—and the Bering Strait.

The historical development of the NSR is summarized following Ship & Ocean Foundation (*5*). Explorations of the Arctic Ocean by western countries started around the eighth century by monks and the tenth century by Vikings. In 1525, a Russian diplomat first proposed the existence of a route that connects the Pacific and the Atlantic via the Arctic Ocean. Although western countries such as Britain, the Netherlands, and Norway devoted themselves to finding the route, they did not succeed until 1879 when an explorer crossed the Arctic. The NSR became a major shipping route when the Soviet Union became isolated from the rest of the world after the 1917 Russian Revolution, because it connected Soviet cities with Asia and thus became a route for delivering construction materials for the Trans-Siberian Railway. Later, it also became an alternative means to the Suez Canal route (SCR) and Cape of Good Hope route that passed the regions of opposing countries. When Glavsevmorput, the Chief Directorate of the NSR, was set up in 1932, the Soviet Union started supervising navigation and building Arctic ports such as Dikson, Tiksi, Mys Shmidta, and Provideniya. Transit on the NSR peaked in 1987, just before the disintegration of the Soviet Union. After a radical decrease in transit between 1987 and 1998 by almost 80%, the NSR has started to regain popularity with shipping companies since 2010 because of the decreasing sea ice extent. Although current transit has still not reached that in 1987, it is expected to keep growing to become one of the major trading routes in the world.

The use of the NSR has three potential advantages. First, it can mitigate potential risks in global maritime transportation. The recent expansion in global trade (*7*) faces a number of risks, including (a) the risk of traffic congestion and accidental collisions (*8*); (b) the risk of choke points along the SCR mainly caused by country-level risks such as the potential effect of the Islamic State



Source: Dynagas Ltd. (*6*)

FIGURE 1 Map of the NSR and SCR between Norway and Japan

and potential closure of the Suez Canal, as happened in 1956–57 when vessels were forced to circumnavigate the Cape of Good Hope; and (c) the risk of piracy around Somalia, which could cause a significant cost to the global economy (*9*). Additionally, the communication via traditional sea routes such as the SCR and Panama Canal route could reach their carrying capacity (*10*). Thus, the dimensionality of a network incorporating the NSR must be adopted to mitigate the risks and satisfy demand because maritime routes have changed little since the Suez and Panama Canals opened in 1869 and 1914, respectively (*11*).

Second, the NSR could benefit the maritime transportation market by offering shorter shipping distances, faster trips, and lower maritime costs. Humpert and Raspotnik (*12*) showed that shipping distance along the NSR is about 60% lower than that along the SCR, while sailing time is about 40% less.

Third, the regions along the NSR are expected to have abundant natural resources. In May 2008, the U.S. Geological Survey (*13*) research paper on the undiscovered resources of oil and natural gas in the Arctic area drew the world's attention. It appraised the amount of undiscovered oil to be 90 billion barrels, natural gas to be 1.7 quadrillion cubic feet, and natural gas liquids to be 44 billion barrels, equivalent to 13% of undiscovered oil and 30% of undiscovered natural gas in the world. It also reported that most of the resources are around the continental shelf of the Arctic Ocean including natural gas on the Russian side and oil on the United States side. For example, the Yamal Peninsula in Russia is a frontier for the natural resource industry. The region of Yamal has 22% of the world's natural gas reserves. After the first plan to develop the area proposed by Gazprom, the largest natural gas extractor in the world, and the Yamal-Nenets autonomous district in 2002, the Comprehensive Development Program for the Yamal Peninsula was introduced in 2007, which aims to compensate the expected decrease in production from west Siberia. By 2030, production from Yamal is expected to reach as much as half that from the whole of Russia in 2012 (*14*). Although it is a challenging program in a harsh environment, it includes the construction of a new transportation system of pipelines and LNG shipments with a view to using the NSR.

SCENARIO DEVELOPMENT

Identification of the Uncertain Factors relating to the NSR

The study team including the authors interviewed local experts in Russia to collect the latest information and understand those uncertain factors that could significantly affect future trade via the NSR. These interviews took place from September 29, 2014 to October 3, 2014. Thirteen experts in eight organizations were interviewed under a semi-structured interview format, which included structured questions about recent NSR use, the government's strategies for maritime transportation via the NSR, the current development of natural resources debated by local stakeholders, and the future perspective of the NSR. Through these interviews, the authors identified three uncertain factors that might affect maritime transportation using the NSR.

The first factor is the bunker fuel price and oil price. In the latter half of 2014, the world witnessed a dramatic fall in both these prices. They are now almost as low as the level of 2009 following the dramatic economic downturn precipitated by the Lehman Brothers bankruptcy in 2008. This price drop was driven by the oversupply of oil from OPEC countries despite the increasing production of shale gas in the United States (*15*). Additionally, the bunker fuel price and oil price have been unstable in the past, which has often led to a vulnerable world economy.

The second uncertain factor is the exchange rate between the Russian ruble (RUB) and US dollar (USD). From the first half of 2014 to the first quarter of 2015, a dramatic fall of nearly 50% occurred. This is the third financial crisis for Russian people after the Soviet breakup and currency slide in 1998 and 2008, respectively (*16*). Hille *et al.* (*17*) reported that Russian banks have been struggling to control the situation, and the central bank announced its market interventions less than a month after allowing the RUB to float. Tanas and Andrianova (*18*) also reported that the Bank of Russia stated that Russia would see GDP shrink by at least 4.5% in 2015 with the oil price staying at 60 USD per barrel and suggested that poor economic stability could be one of the most critical risks to Russia.

The third uncertain factor is the Arctic environment. In 2013, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (*1*) analyzed projections of the Arctic sea ice extent. The IPCC predicted that global mean surface temperatures for 2081–2100 relative to 1986–2005 would increase by 0.3–1.7°C when global warming is slowest and 2.6–4.8°C when global warming is quickest. In addition, year-round reductions in the Arctic sea ice extent by the end of the 21st century are projected to range from 43% to 94%, thus affecting the rises in global mean surface temperature. Moreover, the report showed that the ice extent in the seas of the northern hemisphere could be about 2.0×10^6 km^2 by 2050 (i.e., a very small amount of ice). Furthermore, it also indicated that the extent could reach about 1.5×10^6 km^2 by 2025 when taking the statistical uncertainties into account. Since Arctic sea ice is decreasing from the area near the coastline (of Russia and the United States), it would not be unrealistic to suppose that ice may no longer exist near the Russian coastline by 2025 if the global warming progresses relatively rapidly.

Scenarios

Multiple cases are next presented to incorporate these three uncertain factors. First, as for the values of the bunker fuel price and oil price, the following three cases are assumed: by 2025, the bunker fuel price and oil price are (I) 250 USD and 40 USD, (II) 750 USD and 110 USD, and (III) 500 USD and 80 USD, respectively (*19*, *20*, *21*). The first case represents the condition where the bunker fuel price and oil price were the lowest in the past 10 years, the second case represents the condition where they were the highest in the past 10 years, and the third case represents the averages in the past 10 years.

Second, as for the RUB–USD exchange rate, the following two cases are assumed: by 2025, one RUB is equivalent to (i) 0.015 USD and (ii) 0.030 USD (*22*, *23*). The first case represents the rate in 2015, while the second case represents the constant rate in the past. The reason why this uncertain factor assumes only two cases is that the price has been constant at 0.030 USD for several years, and therefore there is little point in thinking about the recent average.

Third, as for the dynamic change in global warming, the following three cases are assumed: (A) global warming will progress relatively slowly and the amount of sea ice will stay at the current level, (B) global warming will progress at the current growth rate, and (C) global warming will progress relatively rapidly and the sea area near the Russian coastline will be free of sea ice by 2025. These hypothetical dynamic cases affect the periods the NSR is available in a year, since Arctic sea ice melts and thus allows vessels to pass through the NSR under these three cases. The hypothetical dynamic changes in the NSR service period in the three cases are shown in TABLE 1. TABLE 1 assumes the NSR service period is 0 month in 2007–2010 and that is 4 months in 2010–2015 because the Northern Sea Route Information Office (*2*) reported that the NSR regained its popularity as an international shipping route in 2010 and that it was available for three months in 2010, four months in 2011, and five months from 2012 to 2014. TABLE 2 shows the 19 scenarios developed by combining the cases of the three uncertain factors, including a Baseline Scenario where the NSR is unavailable and where other uncertain factors represent the average values.

TABLE 1 Hypothetical Dynamic Changes in the NSR Service Period in the Three Cases

	2007–2010	2010–2015	2015–2020	2020–2025	(2025)
Case A (Slow)	0 month	4 months	4 months	4 months	4 months
Case B (Middle)	0 month	4 months	5.5 months	7 months	8 months
Case C (High)	0 month	4 months	7 months	10 months	12 months

TABLE 2 Description of the 19 Scenarios

	Bunker Fuel Price	Oil Price	RUB	Speed of Melting Ice
Baseline Scenario	500 USD	80 USD	0.030 USD	Zero
Scenario I-i-A	250 USD	40 USD	0.015 USD	A (Slow)
Scenario I-i-B	250 USD	40 USD	0.015 USD	B (Middle)
Scenario I-i-C	250 USD	40 USD	0.015 USD	C (High)
Scenario I-ii-A	250 USD	40 USD	0.030 USD	A (Slow)
Scenario I-ii-B	250 USD	40 USD	0.030 USD	B (Middle)
Scenario I-ii-C	250 USD	40 USD	0.030 USD	C (High)
Scenario II-i-A	500 USD	80 USD	0.015 USD	A (Slow)
Scenario II-i-B	500 USD	80 USD	0.015 USD	B (Middle)
Scenario II-i-C	500 USD	80 USD	0.015 USD	C (High)
Scenario II-ii-A	500 USD	80 USD	0.030 USD	A (Slow)
Scenario II-ii-B	500 USD	80 USD	0.030 USD	B (Middle)
Scenario II-ii-C	500 USD	80 USD	0.030 USD	C (High)
Scenario III-i-A	750 USD	110USD	0.015 USD	A (Slow)
Scenario III-i-B	750 USD	110USD	0.015 USD	B (Middle)
Scenario III-i-C	750 USD	110USD	0.015 USD	C (High)
Scenario III-ii-A	750 USD	110USD	0.030 USD	A (Slow)
Scenario III-ii-B	750 USD	110USD	0.030 USD	B (Middle)
Scenario III-ii-C	750 USD	110USD	0.030 USD	C (High)

MARITIME TRANSPORTATION COST ANALYSIS

Cost Estimation Method

Although many studies have attempted to estimate the unit cost of using the NSR in order to assess its feasibility, the outcomes have varied markedly. The International Northern Sea Route Programme made the first cost estimation from 1993 to 1999, and this suggested that the NSR is feasible for natural resources and wood materials that are produced in the Arctic area. In 2010, the Ship & Ocean Foundation (*5*) analyzed the feasibility of icebreaking bulk container shipments from Hamburg to Yokohama by comparing the year-round use of the NSR/SCR and mixed transportation of the NSR in summer and the SCR in winter. It concluded that there is no priority to use the NSR over the SCR in the current situation.

On the contrary, Arpiainen and Killi (*24*) and Verny and Grigentin (*25*) found that the NSR is feasible. Liu and Kronbak (*26*) included uncertain factors that may affect the unit cost such as the available service period for NSR usage, icebreaking fee, and oil bunker fuel price and concluded that the NSR could be feasible depending on the terms of use. Schøyen and Bråthen (*27*) concluded similarly, while Omre (*28*) found that the mixed use of the NSR and SCR in a year would be feasible. Furuichi and Otsuka (*29*) analyzed the issue by examining container, LNG, and automobile shipments and concluded that LNG shipments via the NSR would be 39% less expensive than those via the SCR.

This study estimates the shipping costs of maritime transportation following these earlier studies, assuming two route options between Northwest Europe and East Asia: the NSR and the SCR. First, it assumes that the shipping cost of a given route consists of the following nine sub-cost components: the capital and depreciation cost, NSR tariff, ice pilot fee, Suez Canal toll, crew cost, maintenance cost, insurance cost, fuel price, and port dues. The annual maritime shipping operation cost on the given route is computed by summing the annual sub-costs over these nine components. Then, the unit transportation cost (USD/m^3) is computed by dividing the estimated annual maritime shipping operation cost by the estimated annual volume of freight carried. Note that this study assumes a type of vessel sailing through the NSR that is similar to the one that delivered LNG from Hammerfest, Norway to Tobata, Japan in December 2012. Its size is assumed to be 147,500 m^3, while the shipbuilding cost is approximated to be the average cost during the recent eight years, which is 200 million USD (*30*).

First, the capital and depreciation cost is the annual repayment for the building cost of a new vessel. The Ship & Ocean

Foundation (*5*) and Furuichi and Otsuka (*29*) considered this to be an interest rate of 7% and a return period of 11 years, which is equivalent to an annual repayment of 10.9% of the building cost for 15 years from a project finance viewpoint. Moreover, since this study supposes a ship of ice class Arc 4 that needs special protection against the ice, the building cost is increased by 20%, as suggested by related studies (*26, 28*). Second, the NSR tariff introduced in March 2014 includes icebreaking assistance provided by the ATOMFLOT. This newly introduced tariff depends on the vessel's gross tonnage, ice class, distance of escort with the icebreaker's support, and navigation period. Although it enables users to decide more flexibly whether to hire icebreakers in each of the seven zones in the Arctic Ocean depending on the ice concentration, in reality, ice class ships are always necessary for securing maritime safety because of the shortage of Russian rescue ports along the NSR (*31*). Thus, this study assumes that the icebreaker pilotage is required in all seven zones, which means that the NSR tariff is assumed to be 268.11 RUB. Third, an ice pilot fee is incurred for hiring a Russian navigational expert, which is assumed to be 673 USD/day (*29*). Fourth, the Suez Canal toll is incurred for using an alternative route to the NSR, namely passing through the Suez Canal. A vessel transporting freight goods between Northern Europe and East Asia must pay this toll when the NSR is unavailable. The toll amount is determined by the Suez Canal Authority depending on freight and volume. Fifth, the crew cost is the labor cost for hiring the crew. An LNG vessel is assumed to have 45 to 50 crewmembers, resulting in a cost of 2 million USD per year (*29*). Sixth, the annual maintenance cost is assumed to be 1.095% of the shipbuilding cost, as reported by Hino (*32*). Seventh, the annual insurance cost of H&M and P&I insurance is assumed to be 0.343% of the shipbuilding cost (*32*). Eighth, the fuel price is estimated under the assumption of the unit costs shown in TABLE 2 for each scenario. The fuel consumption per distance unit is proportional to the square of sailing speed. Further, as resistance is expected to increase against sea ice, the oil consumption rate is increased by 10% in the NSR; moreover, 0.1% of the fuel would be used in the harbor and the amount of machine oil used would be 1% of the bunker fuel used (*29*). Finally, the port dues are assumed to be 0.428 USD/GT/Call (*29*).

The annual freight volume is estimated based on service frequency, vessel capacity, and capacity occupancy. Annual service frequency using the NSR or SCR is estimated based on the NSR service period, navigation speed, and distance between countries. It is assumed that an LNG carrier always makes a round trip with a 90% capacity occupancy. Note that the freight of the LNG shipment is only demanded one way; for instance, there are LNG freights from Norway to Japan, but no freights from Japan to Norway. In addition, in this study, the origins of the LNG shipments are Russia, Norway, and France and the destinations are Japan, China, and South Korea. Finally, the study analyzes the unit cost of mixed transportation via the NSR and SCR (termed SCR&NSR herein) considering the available period of the NSR.

Results of the Cost Estimation Analysis

TABLE 3 shows the results of estimating the unit costs and sailing times of LNG trade from Norway, Russia, and France to Japan in 24 cases consisting of three cases of the bunker fuel price and oil price and two cases of the RUB–USD exchange rate with four types of NSR periods available: 4.0, 5.5, 7.0, and 10.0 months per year. Note the unit costs were derived from dividing the estimated annual maritime shipping operation costs by annual volumes of freight carried for each case. Each case assumes different combinations of bunker fuel price/oil price, RUB-USD exchange rate, and NSR periods for estimating the annual maritime shipping operation costs, using the data shown in TABLE 2.

First, in all cases except some cases of LNG trade between France and Japan, the unit cost of the NSR is cheaper than that of the SCR. This may be because the NSR tariff is cheaper than the SCR toll and the shipping distance along the NSR is shorter than that along the SCR even though the shipbuilding cost of the NSR is higher than that of the SCR. Second, the longer the NSR-available period is, the cheaper the weighted average cost of the SCR&NSR is. This finding is reasonable because the unit cost of the NSR is always cheaper than that of the SCR, while the impact of the cheaper unit cost of the NSR increases as the available period becomes longer. Third, the sailing time along the NSR is shorter than that along the SCR because the shipping distance of the NSR is shorter than that of the SCR. Note that some cases show the cost of the SCR&NSR to be more expensive than that of the SCR even though the sailing time along the NSR is shorter than that along the SCR. This is because the increase in the unit cost caused by the more expensive shipbuilding cost via the NSR would be more dominant than the decrease in the unit cost caused by the cheaper NSR tariff and lower fuel price of the NSR when the difference in shipping distance between them is small. This finding suggests that the use of the NSR should not be discussed only from the viewpoint of sailing time but also from the perspective of both sailing time and transportation cost.

TABLE 3 Estimated Unit Cost of LNG Trade from Norway, Russia, and France to Japan by NSR-Available Period

NSR-Available Months	Origin	Destination	Scenario I-i			Scenario I-ii			Scenario II-i			Scenario II-ii			Scenario III-i			Scenario III-ii		
			SCR	NSR	SCR &NSR	SCR	NSR	SCR &NSR	SCR	NSR	SCR &NSR	SCR	NSR	SCR &NSR	SCR	NSR	SCR &NSR	SCR	NSR	SCR &NSR
4.0	Norway	Japan	51.01 (31.1)	37.30 (19.3)	50.65	51.01 (31.1)	43.34 (19.3)	53.24	62.37 (31.1)	42.94 (19.3)	60.86	62.37 (31.1)	48.98 (19.3)	63.45	73.72 (31.1)	48.59 (19.3)	71.07	73.72 (31.1)	54.63 (19.3)	73.65
	Russia	Japan	50.72 (30.9)	36.80 (18.2)	50.24	50.72 (30.9)	42.84 (18.2)	52.83	62.01 (30.9)	41.96 (18.2)	60.19	62.01 (30.9)	48.00 (18.2)	62.78	73.29 (30.9)	47.11 (18.2)	70.14	73.29 (30.9)	53.15 (18.2)	72.73
	France	Japan	45.08 (26.9)	38.77 (22.6)	47.37	45.08 (26.9)	44.82 (22.6)	49.96	54.91 (26.9)	45.86 (22.6)	57.16	54.91 (26.9)	51.90 (22.6)	59.74	64.75 (26.9)	52.95 (22.6)	66.94	64.75 (26.9)	58.99 (22.6)	69.53
5.5	Norway	Japan	51.01 (31.1)	38.04 (19.7)	48.14	51.01 (31.1)	44.08 (19.7)	51.59	62.37 (31.1)	43.69 (19.7)	57.21	62.37 (31.1)	49.73 (19.7)	60.66	73.72 (31.1)	49.33 (19.7)	66.28	73.72 (31.1)	55.37 (19.7)	69.73
	Russia	Japan	50.72 (30.9)	37.54 (18.5)	47.71	50.72 (30.9)	43.58 (18.5)	51.16	62.01 (30.9)	42.70 (18.5)	56.46	62.01 (30.9)	48.74 (18.5)	59.92	73.29 (30.9)	47.86 (18.5)	65.21	73.29 (30.9)	53.90 (18.5)	68.67
	France	Japan	45.08 (26.9)	39.52 (23.0)	46.67	45.08 (26.9)	45.56 (23.0)	49.69	54.91 (26.9)	46.61 (23.0)	56.12	54.91 (26.9)	52.65 (23.0)	59.14	64.75 (26.9)	53.70 (23.0)	65.56	64.75 (26.9)	59.74 (23.0)	68.58
7.0	Norway	Japan	51.01 (31.1)	38.49 (19.9)	45.63	51.01 (31.1)	44.53 (19.9)	49.95	62.37 (31.1)	44.13 (19.9)	53.56	62.37 (31.1)	50.18 (19.9)	57.88	73.72 (31.1)	49.78 (19.9)	61.49	73.72 (31.1)	55.82 (19.9)	65.80
	Russia	Japan	50.72 (30.1)	33.82 (18.8)	41.15	50.72 (30.9)	39.86 (18.8)	45.68	62.01 (30.9)	38.98 (18.8)	48.41	62.01 (30.9)	45.02 (18.8)	52.94	73.29 (30.9)	44.13 (18.8)	55.66	73.29 (30.9)	50.17 (18.8)	60.19
	France	Japan	45.08 (26.9)	39.97 (23.2)	45.52	45.08 (26.9)	46.01 (23.2)	49.29	54.91 (26.9)	47.05 (23.2)	54.37	54.91 (26.9)	53.10 (23.2)	58.15	64.75 (26.9)	54.14 (23.2)	63.23	64.75 (26.9)	60.18 (23.2)	67.00
10.0	Norway	Japan	51.01 (31.1)	39.00 (20.8)	42.77	51.01 (31.1)	45.04 (20.8)	48.06	62.37 (31.1)	44.65 (20.8)	49.41	62.37 (31.1)	50.69 (20.8)	54.70	73.72 (31.1)	50.29 (20.8)	56.06	73.72 (31.1)	56.33 (20.8)	61.34
	Russia	Japan	50.72 (30.9)	35.31 (19.7)	39.03	50.72 (30.9)	41.35 (19.7)	44.40	62.01 (30.9)	40.47 (19.7)	45.12	62.01 (30.9)	46.51 (19.7)	50.49	73.29 (30.9)	45.62 (19.7)	51.21	73.29 (30.9)	51.66 (19.7)	56.58
	France	Japan	45.08 (26.9)	44.73 (24.2)	47.25	45.08 (26.9)	50.78 (24.2)	52.42	54.91 (26.9)	51.82 (24.2)	55.01	54.91 (26.9)	57.86 (24.2)	60.19	64.75 (26.9)	58.91 (24.2)	62.77	64.75 (26.9)	64.95 (24.2)	67.95

Note 1: The unit cost is USD/m^3 in 2014 prices.

Note 2: The unit cost of SCR&NSR is a weighted average cost considering the available period of the NSR.

Note 3: Parentheses denote the sailing time (days) on each route.

Note 4: Representative ports are assumed to be Hammerfest in Norway, Sabetta in Russia, Le Havre in France, and Yokohama in Japan for estimating the maritime operating cost.

ECONOMIC IMPACT ANALYSIS

This study applies the Global Trade Analysis Project (GTAP) model (*33*) for the economic impact analysis. The standard GTAP model is a multi-region, multi-sector computable general equilibrium (CGE) model with perfect competition and constant returns to scale. It is currently the most widely used international CGE model (*34*). The database used in this study is the GTAP 8 Data Base, which was released in March 2012. It contains complete bilateral trade information, transportation, and protection linkages in which it boasts two reference years (2004 and 2007) as well as 129 regions for 57 commodities.

For analytical simplicity, this study aggregates these data into 22 regions and seven commodities. The 22 aggregated regions are Japan, China, South Korea, Australia, Indonesia, Malaysia, the Rest of Southeast Asia, the United States, Norway, Spain, France, Egypt, Russia, Qatar, Oman, the United Arab Emirates, the Rest of Western Asia, Nigeria, the Rest of North Africa, the Caribbean, Peru, and the Rest of the World. The seven aggregated commodities are Gas, Oil, Electricity, Light Industry, Petrochemical Industry, Heavy Industry, and Others.

The presented simulation analysis estimates the impacts of the NSR in 2025 by using the GTAP 8 Data Base, whose base year is 2007. The international economy in 2025 is estimated in four sequential simulations following the method introduced by Shibasaki *et al.* (*35*). For the estimations in each sequence, changes in the following factors within each region are shocked to conform to the reality based on statistics taken from the United Nations, International Monetary Fund, and International Labor Office on population, skilled labor, unskilled labor, capital, natural resources, tariff rate, export subsidy, and total factor productivity. The first sequence estimates the trend from 2007 to 2010 by inputting changes in the above factors into the GTAP model, along with the 2007 data from the GTAP 8 Data Base. The second, third, and fourth sequences are simulated along with the data estimated by the previous sequence: the second sequence estimates changes from 2010 to 2015, the third from 2015 to 2020, and the fourth from 2020 to 2025. Note that in all these sequences, the trade elasticity of gas in the international dataset of the GTAP model is changed to match that of oil.

In the first sequence, exogenous factors are given to reflect the volume of LNG trade in Japan in 2010. This is because Japan's LNG trade, particularly with Russia, drastically changed from a small amount in 2007 to 8,369 million m^3 in 2010 (*36*). This drastic increase was mainly caused by the development of the Sakhalin Island in Russia.

As for exogenous changes in the second, third, and fourth simulations, a percentage change from the unit cost of using only the SCR to the average unit cost of using both the SCR and the NSR is given to one of the parameters in the GTAP model for each simulation. The trade volume is estimated as follows:

$$QXS^{*}(i,r,s) = \{1 + ams(i,r,s)\}QXS(i,r,s) \tag{1}$$

where $QXS(i,r,s)$ is the quantity of commodity i traded from region r to region s before the change in transportation service, $QXS^{*}(i,r,s)$ is the quantity of commodity after the change, and $ams(i,r,s)$ represents the augmenting technical change coefficient in the GTAP model. The change in ams means the negative impact on the decay of imports of commodity or service *i* from region *r* imported by region *s*. This study assumes $ams(i,r,s)$ to be an exogenous variable, which is estimated as

$$ams(i,r,s) = \theta_i \left(Cost_{SCR}(i,r,s) / Cost_{SCR\&NSR}(i,r,s) - 1 \right) \tag{2}$$

where $Cost_{SCR}(i,r,s)$ is the unit cost of shipping commodity i traded from region r to region s when using the SCR throughout a year, $Cost_{SCR\&NSR}(i,r,s)$ is the average unit cost of shipping commodity i traded from region r to region s when using the NSR in summer and the SCR in winter, and θ_i is a given parameter relating to commodity i. θ_i is introduced to incorporate other factors affecting the shipping cost relating to commodity i. θ_i is assumed to vary among 20, 60, and 100 for trade between Japan and Russia, while it is 100 for the other regions in this case study. This is because LNG trade from Sakhalin Island is expected to influence trade with Russia heavily, but its impact is uncertain. When the share of LNG exports from Sakhalin Island out of total LNG exports from Russia increases, the impacts of the national average change in the maritime transportation cost from Russia along the NSR could reduce.

This study also highlights a portfolio of LNG import sources for Japan. According to the International Energy Agency (*37*), 90% of the LNG imported by Japan in 2013 came from eight countries, namely Australia, Brunei, Indonesia, Malaysia, Oman, Qatar, Russia, and the United Arab Emirates, whereas Japan's LNG import sources are biased to Southeast Asia and the Middle East compared with Russia. Additionally, LNG from Southeast Asia and the Middle East could pass though choke points such as the Strait of Hormuz, Strait of Malacca, and South China Sea, whereas that from Russia comes from the north passing no choke points. This fact may mean that Japan faces a risk to energy security. Thus, the use of the NSR could contribute to diversifying the LNG import portfolio and reducing energy security risks for Japan. Finally, the standard deviation of shares in LNG trade between Japan and three regions (Southeast Asia, the Middle East, and Russia) is estimated by using the simulation results of the GTAP model.

Results of the Economic Impact Analysis

TABLE 4 shows the simulation results regarding the growth rate of Japan's GDP from 2010 to 2025 and the standard deviation of LNG trade between Japan and the three regions in 2025. First, these results show that the Baseline Scenario leads to an increase in Japan's GDP by 14.61% from 2010 to 2025, while Scenario III-i-B ($\theta = 100$) leads to the highest increase in GDP (14.80%). This finding may suggest that although the use of the NSR has a positive impact on Japan's macroeconomy, this effect may be quite limited. It also shows that the mixed use of the NSR and SCR under the current condition of rapidly melting sea ice positively influences Japan's macroeconomy compared with that under a slower ice-melting condition. This result is reasonable because the weighted average cost of LNG becomes cheaper as longer periods of the NSR become available. Further, the mixed use of the NSR and SCR under a cheaper RUB positively influences Japan's macroeconomy compared with that under a higher RUB. This finding is also understandable because the NSR tariff is cheaper under a lower RUB and this reduces the weighted average cost. A higher θ has a greater impact on Japan's macroeconomy because a higher ratio of LNG imported from the Yamal Peninsula contributes to reducing unit costs, which increases Japan's GDP.

TABLE 4 Growth Rate of Japan's GDP from 2010 to 2025 and the Standard Deviation of the Three Regions in 2025

θ		100			60			20		
Speed of Melting Arctic Ice	Zero	A (Slow)	B (Middle)	C (High)	A (Slow)	B (Middle)	C (High)	A (Slow)	B (Middle)	C (High)
Baseline Scenario	14.61 (34.78)									
Scenario I-i		14.61 (33.89)	14.66 (19.69)	14.73 (35.32)	14.61 (34.26)	14.64 (26.47)	14.67 (19.08)	14.61 (34.62)	14.62 (32.70)	14.62 (30.57)
Scenario I-ii		14.61 (34.78)	14.62 (30.59)	14.65 (21.96)	14.61 (34.78)	14.62 (32.52)	14.63 (28.20)	14.61 (34.78)	14.61 (34.11)	14.62 (33.10)
Scenario II-i		14.62 (31.38)	14.69 (21.60)	14.77 (47.47)	14.62 (32.95)	14.65 (22.50)	14.69 (22.07)	14.61 (34.23)	14.62 (31.83)	14.63 (29.06)
Scenario II-ii		14.61 (34.78)	14.64 (25.11)	14.69 (21.01)	14.61 (34.78)	14.63 (29.83)	14.65 (22.78)	14.61 (34.78)	14.62 (33.45)	14.62 (31.90)
Scenario III-i		14.63 (29.11)	14.71 (29.17)	14.80 (53.33)	14.62 (31.84)	14.66 (20.06)	14.71 (28.44)	14.61 (33.95)	14.62 (31.13)	14.63 (27.83)
Scenario III-ii		14.61 (34.07)	14.66 (20.12)	14.72 (32.86)	14.61 (34.37)	14.63 (26.88)	14.67 (19.33)	14.61 (34.65)	14.62 (32.80)	14.62 (30.78)

Note 1: Upper denotes the growth rate of Japan's GDP (%) from 2010 to 2025.

Note 2: Lower in parentheses denotes the standard deviation in 2025 of LNG trade between Japan and the three regions: Southeast Asia, the Middle East, and Russia.

Next, the simulation result of the Baseline Scenario shows that the standard deviation of trade volumes among the three regions is 34.78% in 2025. Most scenarios except Scenario II-i-C ($\theta = 100$) and Scenario III-i-C ($\theta = 100$) lead to a smaller standard deviation than that in the Baseline Scenario. This finding may suggest that the NSR contributes to diversifying the LNG import portfolio for Japan. These two scenarios have higher standard deviations because the volume of LNG imported from Russia is calculated to increase drastically, making the portfolio biased. The results also show that Case A (Slow) leads to the highest standard deviation out of the three cases regarding the speed of melting ice in all scenarios except Scenarios I-i ($\theta = 100$), II-i ($\theta = 100$), and III-i ($\theta = 100$). This is because too short an available NSR period provides poor LNG trade from Russia, which results in a larger difference in LNG trade between Russia and the other two regions. Case C (High) leads to a higher standard deviation than Case A (Slow) in the above three scenarios because a longer NSR-available period could increase LNG trade from Russia, which results in a larger difference between Russia and the other two regions.

CONCLUSIONS

This study examined the feasibility of using the NSR as an LNG shipping route and analyzed the possible impacts on Japan's future macroeconomy and LNG import diversification. The results showed that the NSR is feasible; it contributes to Japan's GDP in 2025 by a maximum of 0.19% as well as to diversifying the LNG import portfolio through decreasing the standard deviation by a maximum of 15.7%. The present study also showed that the results are quite robust even under uncertain factors regarding the Arctic environment, bunker fuel price, and the RUB–USD exchange rate.

The above results may suggest that Japan's future energy mix strategy, particularly concerning the variety of import sources, should be expanded by using the NSR. The expected impacts could be more or less similar to cases in neighboring countries such as South Korea and China, which also import huge volumes of LNG. However, recent policy actions in Japan are quite different from theirs. Although Japan's government is less proactive about researching the potential of using the NSR, the governments in South Korea and China have recently become more interested in the NSR. For instance, in January 2014, South Korea's government reduced port dues by 50% for ships that sail through the NSR. It has also established a cooperation organization with shipowners, shippers, and research institutes to work with Arctic countries, such as by conducting a training program for sailors using the NSR. In China, the China–Nordic Arctic Research Center was established in Shanghai to enhance its knowledge on and to study international relationships in the Arctic region. China is not just planning to keep building icebreakers, however. It has also built a satellite system that covers the Arctic region (the BeiDou navigation satellite system).

One of the reasons for the different recent actions between Japan and China/South Korea is that while the latter countries are directly connected with Russia and use pipeline networks to import natural gas, Japan can import gas only through maritime transportation. In this sense, the NSR, one of the most important maritime transportation routes for importing LNG from Russia, should be highlighted in Japanese policy. This fact may suggest that natural gas transportation through a pipeline network should be examined to compare the potential impacts of using the NSR. This issue is left to future research.

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