Arctic Sovereignty and the Northwest Passage

by

Brandon LaCarte

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Queen's University
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Abstract

A warming arctic suggests that Canada will need to prepare for the possibility that the Northwest Passage will open for marine navigation in the future. To complicate matters, the United States does not recognize Canada's sovereignty over the Northwest Passage. This paper provides a detailed examination of the economic implications of the policy issues arising from these arctic challenges; these economic implications have only marginally been studied. It introduces a stochastic control model where shipping lines may choose to invest in arctic or bluewater ships - the government may influence this decision through investment in the north. Furthermore, a game-theoretic analysis provides conditions under which Canada would wish to undergo high or low investment in the Northwest Passage to assert its sovereignty in face of the United States' position. We conclude that if Canada is to invest optimally and deliver effective policies, the government must carefully consider whether sovereignty is worth the investment and whether it agrees with the strategic priorities of the United States.

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1 Introduction

In recent years, the Northwest Passage has become an increasingly popular topic of debate among Canadian policy makers and the media. The story is as follows: the arctic is warming, promising to render the Northwest Passage navigable by marine vessels sometime this century, thus necessitating investment by Canada in order to be prepared for the resulting security, environmental and social policy challenges. To compound these challenges, the United States does not recognize Canada's sovereignty over the Northwest Passage and argues instead that it is an international straight. For many Canadians this disagreement with the United States sparks strong feelings of nationalism. From a practical policy perspective, however, the challenge for Canada is to determine how much sovereignty matters for Canadian policy, whether sovereignty over the Northwest Passage is justified by the cost of investing for it, and whether such investment can be undertaken in a manner consistent with American preferences.

The objective of this paper is to thoroughly analyze the issue of the Northwest Passage in order to inform an appropriate government policy response. In doing so, the paper attempts to clarify the economic dimensions underlying the issue which have received only marginal attention in the policy literature; it considers the factors which may lead to increased marine navigation in the Northwest Passage, as well as the considerations which should inform the government's level of investment in response to this challenge. In particular, two strands of economic analysis are provided. First, a stochastic control model captures a shipping line's decision of whether to invest in arctic vessels in the hopes of eventually sailing through the Northwest Passage. Government investment would have a positive influence on this possibility, and investment may also be necessary in order for Canada to respond to the challenges posed by potential maritime traffic. Second, the disagreement over the legal status of the Northwest Passage between Canada and the United States is put in context and the two countries' strategic motives are considered in a game-theoretic framework.

The present Canadian approach with respect to the Northwest Passage dispute has been to 'agree to disagree' with the United States and not directly address the issue through open negotiation. The analysis in this paper, however, makes the case that Canada ultimately cannot ignore the issue of sovereignty over the Northwest Passage. Accordingly, current and future policy should be informed by an underlying objective to either secure or eschew sovereignty over the Passage.

The structure of the paper is as follows - in Section 2, the environmental evidence concerning the Northwest Passage is summarized and the future feasibility of arctic shipping is discussed. Following this background, Section 3 will present a stochastic control model for shipping lines, and the results are related to government policy. Section 4 discusses the legal uncertainty of the Northwest Passage, including the Canadian and American perspectives; it also surveys some of the principal motives for why sovereignty may matter to Canadian policy makers. In Section 5 a game between Canada and the United States is presented where both countries determine the legal status of the Northwest Passage. This game allows differing views in the policy literature to be placed in context and is used to generate advice for Canadian policy. Section 6 discusses future research, and Section 7 concludes.

2 The Northwest Passage

2.1 Climate Change, the Arctic Environment and the Northwest Passage

The principal driver of the policy discussion related to the Northwest Passage has been climate change. A warming arctic allows for the future possibility that, for the first time, the Northwest Passage may be open for seasonal marine navigation. Indeed, it has already opened recently - in 2007 the Northwest Passage opened for the first time during part of the summer after arctic sea ice attained a new record

low.[1] In reference to this event, the U.S. National Snow and Ice Data Center's senior research scientist, Mark Serreze, commented that "The observed rates of change have far outstripped what we projected" and that an ice-free arctic in summer months was a reasonable expectation, "within our lifetimes and certainly within our children's lifetimes."[2] Most recently, the National Snow and Ice Data Center has reported that the maximum extent of winter sea ice cover for 2008-09 was the fifth lowest on record.[3] Moreover, the six lowest maximum events since satellite observation began in 1979 have all occurred in the past six years.[4]

These recent observations are in agreement with a larger body of scientific evidence that the arctic sea ice is melting. The 2004 Arctic Climate Impact Assessment (ACIA) reported that over the past thirty years, the annual average sea ice decreased by eight percent - nearly one million square kilometers - and that this rate is accelerating. The ACIA further suggests that the Arctic Ocean may be ice-free in the summer by the end of the century.[5] In sharp contrast to this prediction, satellite observations by the U.S. National Snow and Ice Data Center indicate that the arctic could be seasonally ice-free by 2030.[6] In April 2009, Warwick Vincent, director of the Center for Northern Studies at Laval University commented that "2013 is starting to look as though it is a lot more reasonable as a prediction."[7]

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[1]David Biello."The North Pole is Melting", Scientific American, September 21, 2007, `http://www.sciam.com/article.cfm?id=the-north-pole-is-melting`

[2]David Biello."Fabled Northwest Passage opens up for business in the arctic", Scientific American, Aug 27, 2008, `http://www.sciam.com/blog/60-second-science/post.cfm?id=fabled-northwest-passage-open-for-b-2008-08-27`

[3]Editorial. "Arctic ice is melting", Washington Post, April 11 2009, p.A12

[4]Ibid.

[5]ACIA. Impacts of a Warming Arctic: Arctic Climate Impact Assessment, Cambridge: University Press, 2004, p.13. The ACIA was produced by the Arctic Council and the International Arctic Science Committee; the Arctic Council is a high-level intergovernmental forum including Canada, Denmark, Finland, Iceland, Sweden, Russia and the United States.

[6]Michael Byers and Suzanne Lalonde."Who controls the Northwest Passage?", 2006, p.2. Henceforth known as "Byers and Lalonde".

[7]Editorial. "Arctic ice is melting", Washington Post, April 11 2009, p.A12

Furthermore, Stroeve et al. (2007) examined eighteen climate models used by Intergovernmental Panel on Climate Change and concluded that these models may not be fully capturing the effect of greenhouse gases on the melting of the arctic ice. Accordingly, the transition to an ice-free state may occur "well-within this century."[8]

Despite the evidence that an ice-free arctic will be a reality sometime within this century, it is important to make a distinction between the trends which relate to the Arctic Ocean, and the state of the Northwest Passage. In the short term, there is evidence to suggest that despite the warming of the arctic as a whole, there will be inter-annual variability in the ice conditions of the Northwest Passage. For vessels operating in the Northwest Passage the barrier to navigation has traditionally been "multi-year" ice (equivalently old ice) which can attain thicknesses of ten metres and achieve the hardness of concrete; this is in contrast to first-year ice, which poses much less of a threat to vessels.[9] Wilson et al. (2004) have noted that melting first-year ice around the Queen Elisabeth Islands areas might cause multi-year ice to drift into the Northwest Passage and/or a southern shift of the Beaufort sea ice pack, which would increase the quantity of multi-year ice in the Northwest Passage.[10] This phenomenon could render navigation extremely difficult as such ice could create blockages or 'choke-points' in the Passage. While these concerns add to the uncertainty concerning the timing of the Northwest Passage's opening, however, they do not reverse

[8]Julienne Stroeve, Marika M. Holland, Walt Meier, Ted Scambos and Mark Serreze. "Arctic sea ice decline: Faster than forecast", Geophysical Research Letters, Vol. 34, p.5

[9]Byers and Lalonde, p.3

[10]K.G Wilson, J. Falkingham, H. Melling and R. De Abreu. "Shipping in the Canadian Arctic: Other Possible Climate Change Scenarios.", p.4. Available at the National Oceanic and Atmospheric Administration: `http://www.arctic.noaa.gov/detect/KW_IGARSS04_NWP.pdf`
Further, the ACIA Report incorporates these findings into their "Key Finding #6": "Results of research at Canada's Institute of Ocean Sciences suggest that the amount of multi-year sea ice moving into the Northwest Passage is controlled by blockages or "ice bridges" in the northern channels and straits of the Canadian Arctic Archipelago. With a warmer arctic climate leading to higher temperatures and a longer melt season, these bridges are likely to be more easily weakened (and likely to be maintained for a shorter period of time each winter) and the flushing or movement of ice through the channels and straits could become more frequent. More multiyear ice and potentially many more icebergs could thus move into the marine routes of the Northwest Passage, presenting additional hazards to navigation". ACIA, pp.84-85

the general consensus that it will be navigable by vessels sometime this century.[11]

2.2 The Potential of Arctic Shipping

An open Northwest Passage offers two principal benefits to world shipping. First, the Passage offers a substantial distance savings for many routes between Asia and the U.S. east coast vis-*à*-vis the Panama Canal; the Passage offers distance savings of up to 7,000 kilometers.[12] Second, it permits navigation by substantially larger vessels than the Panama Canal. As an illustration, in 1969 the 155,000 ton ice-strengthened supertanker *Manhattan* traversed the Northwest Passage. The Panama Canal, by contrast, can accommodate vessels only up to 70,000 tons.[13] This is a further potential cost-savings for shipping companies since maritime shipping generally exhibits economies of scale in ship size.[14] There is arguably a third advantage: the waters of the Northwest Passage are relatively calm in contrast to ocean transit where storms are more dangerous.[15] The benefits of the Northwest Passage become stronger when placed against the expected future state of world shipping: world trade is forecast to increase significantly by 2020 when 30% of the world's shipping fleet is expected to be too large to pass through the Panama Canal.[16]

To increase the clarity of the above comments, it is helpful to define a general equation

[11]David Barber, Louis Fortier and Michael Byers. "The Incredible Shrinking Sea Ice", Policy Options, December 2005-January 2006, p. 67. Barber et al. note that: "In recent years, the pack ice edge has retreated north, and it now lies at the northern limit of the McClure Straight. Once this edge retreats beyond the entrance way to McClure Straight we can expect a dramatic reduction in the amount of multiyear sea ice moving into the Northwest Passage. Given the current trajectory, this will likely happen in the next decade." Also see Byers and Lalonde, p.4

[12]Byers and Lalonde, p.5

[13]The Panama Canal is undergoing expansion, however it will remain much smaller than the Northwest Passage.

[14]Martin Stopford. Maritime Economics, New York: Routledge, 1997, p.158

[15]Byers and Lalonde, p.5

[16]BBC News."Ships power into faster future", BBC News, December 7, 2005, `http://news.bbc.co.uk/1/hi/technology/4503686.stm`

for the annual unit cost of a ship:[17]

$$C_t = \frac{OC_t + PM_t + VC_t + CHC_t + K_t}{DWT_t} \tag{2.1}$$

where OC_t is the operating cost, PM_t is a periodic maintenance provision, VC_t is the voyage cost, CHC is the cargo-handling cost, K_t is the capital cost and DWT_t is the ship deadweight; all costs are expressed per annum with the subscript t.

Further, we may define the annual operating cost: [18]

$$OC_t = M_t + ST_t + MN_t + I_t + AD_t \tag{2.2}$$

where M_t is the manning (crew) cost, ST_t are stores, MN_t is routine repair and maintenance, I_t is insurance and AD_t represents administrative costs.

Finally, the annual voyage cost may be defined:[19]

$$VC_t = FC_t + PD_t + TP_t + CD_t \tag{2.3}$$

where FC_t are the fuel costs for the ship's main engines and auxiliaries, PD_t are port dues, TP_t are tug and pilotage fees, and CD_t are canal dues (where applicable).

Placing together equations (2.1)-(2.3), the vessel unit cost function becomes:

$$C_t = \frac{((M_t + ST_t + MN_t + I_t + AD_t) + PM_t + (FC_t + PD_t + TP_t + CD_t) + CHC_t + K_t)}{DWT_t} \tag{2.4}$$

One must be careful in speculating on costs since, among other variables, they are specific to vessel type, prevailing market conditions, and the nature of the planned route. From equation (2.4), however, should firms decide to travel through the Passage in the future the main reduction in unit costs is likely to come from allowing larger ships to be built, i.e. from increasing DWT_t. Stopford (1997) emphasizes the fact that there are scale economies in ship size: "unit costs generally fall as the size of the ship increases because capital, operating and cargo handling costs do not increase

[17]Stopford, p. 158
[18]Stopford, p. 161
[19]Stopford, p.166

proportionately with the cargo capacity".[20] Fuel consumption, FC_t may be affected by the distance savings of the Northwest Passage, and a shorter distance will create time savings for shipping companies.[21] Vessels may be able to save in canal fees, CD_t, by traveling through the Northwest Passage as opposed to paying the dues of the Panama Canal.[22] Finally, there is the revenue side to consider: a ship with a larger DWT_t can supply more cargo to a given destination.

Despite the above cost advantages, however, there are some who are skeptical of the possibility of arctic shipping. Griffiths (2004) has cited several concerns including the fact that insurance rates, I_t, would be much higher for a vessel transiting through the Northwest Passage.[23] Moreover, according to Griffiths, a short navigation season (the arctic summer), lack of predictability of ice movement, insufficient navigational charts, and the high expenses of polar vessels may negate any cost advantages.[24]

What is important to note is that while these objections warrant serious consideration, some of them may be only near-term factors. The time horizon of the discussion is very important. Based on current evidence, environmental conditions are forecast to become more favourable in the long-run. Moreover, many of these deterring factors are partially a function of government policy. Investment in infrastructure, including arctic ports and search and rescue capabilities, would provide greater security and certainty to vessels choosing to transit the Northwest Passage. Investment in scientific research would improve navigational aids. In conjunction with improving

[20] Stopford, p.25

[21] However, this must be considered carefully. Vessels traveling through the Northwest Passage may require reinforced hulls; these vessels are more costly to operate in open water. Therefore, for a vessel of the same size comparing a Panama Canal route to a Northwest Passage route, it must compare the reduced distance of the voyage to the required increase in blue water fuel consumption.

[22] This would depend on whether Canada is able to charge transit fees in the Northwest Passage and whether it chooses to. The option of transit fees is revisited later in this paper.

[23] Franklin Griffiths."Pathetic Fallacy: That Canada's Arctic Sovereignty is on Thinning Ice", Canadian Foreign Policy, Spring 2004, pp. 9-11

[24] Ibid.

environmental conditions, such investments may in the long-run lower the insurance rate premium to vessels traversing the Northwest Passage. The notion that government policy partially determines the likelihood of shipping within the Passage will be subsequently revisited.

While the passage may become attractive for transnational shipping at some future date, there is a more immediate and agreed-upon source of demand for the Passage - shipping related to arctic resources. Byers (2008) notes "The greatest incentive for future shipping, however, is the presence of oil and gas".[25] According to the US Geological Survey, approximately 25 percent of the world's future energy reserves are contained in the arctic, and it is expected to be a major area of future resource development.[26] The importance of potential arctic resources becomes clear when one considers the investments currently being made in the north: Exxon Mobil is spending $585 million on a five-year expedition, and British Petroleum is investing approximately $1.2 billion in the Canadian Beaufort Sea and Mackenzie Delta area.[27] Moreover, other natural resources including diamonds, gold, base metals and uranium have all attracted attention from a variety of stakeholders and may increase future commercial shipping as resource projects move from exploration to production stages.[28]

2.3 Simulation Evidence and the Northwest Passage

Somanathan et al. (2006) constructed a simulation for vessels traveling through the Northwest Passage along two routes, Yokohoma to St. Johns, and Yokohoma to New

[25]Michael Byers. "Unfrozen Sea: Sailing the Northwest Passage", Policy Options, May 2007, p.31

[26]Senate of Canada. Proceedings of the Standing Senate Committee on Energy, the Environment and Natural Resources, Second Session, Thirty-ninth Parliament, 2007-08, May 1, 2008

[27]Ibid.

[28]Byers and Lalonde, p.6

York, and compared them with a corresponding route through the Panama Canal.[29] While the Northwest Passage may melt in the future to allow summer transit for a wider range of vessel classes, the simulation was run assuming that an appropriately ice-strengthened ship (Canadian Arctic Class 3, or CAC3) would be transiting the passage year-round under current ice conditions. The CAC3 and bluewater ship were assumed to have the same cargo capacity, which removes the natural advantage of the Northwest Passage in allowing larger vessels that would realize scale economies.

Using historical ice regime data, probabilistic ice regimes were constructed for the Northwest Passage, while the Panama Canal simulation included probabilistic wait times and variability in ship speed due to wind and wave conditions. Their model predicted a lower required freight rate for the Northwest Passage route from Yokohoma to St. Johns, even with a 50% construction premium of a CAC3 ship over a traditional bluewater ship; New York to Yokohoma, however, was not desirable through the Northwest Passage, even with a 10% construction premium on a CAC3 ship.[30] While this simulation is by no means a conclusive argument in favour of shipping, it highlights the need for more analysis, especially given that ice conditions are forecast to change in the future. Somanathan et al note: "Arctic ice has been reported to be thinning and shrinking in extent, and if this trend continues the speed of transit from a CAC3 ship will increase, in turn increasing the economic incentive of the Northwest Passage."[31]

[29]Saran Somanathan, Peter C. Flynn and Jozef Szymanski. "The Northwest Passage: A Simulation", Proceedings of the 2006 Winter Simulation Conference, 2006. Available at: `http://www.informs-sim.org/wsc06papers/200.pdf`

[30]The study, however, assumed ship size was equal among both routes, eliminating one major advantage of the Northwest Passage.

[31]Somanathan et al, p.1583

3 A Stochastic Control Model for Shipping Lines

Here we introduce a stochastic control model outlining the potential decision faced by shipping companies. In this decision problem, a shipping line (SL) must select a fleet that may be composed of "arctic" and/or "bluewater" ships. Arctic ships are able to traverse the Northwest Passage; however, bluewater ships must travel through the Panama Canal, or alternatively, their most cost-efficient bluewater route.[32] There is uncertainty over whether the Northwest Passage will open to allow shipping, and should the passage not open, arctic ships produce a lower level of profit than bluewater ships.[33] When able to traverse the Northwest Passage, however, arctic ships yield a higher level of profit than bluewater ships. Consequently, the assumptions regarding payoffs are explicitly stated below:

$$\pi_{NA} > \pi_{PA} \tag{3.1}$$

$$\pi_{PB} > \pi_{PA} \tag{3.2}$$

$$\pi_{NA} > \pi_{PB} \tag{3.3}$$

$$\pi_{PB} > 0 \geq \pi_{NB} \tag{3.4}$$

where the first subscript represents the route (N for the Northwest Passage, and P for the Panama Canal), and the second is for an arctic (A) or bluewater (B) ship. Assumption (3.1) indicates that an arctic ship is more profitable when traveling through the Northwest Passage than the Panama Canal. Assumption (3.2) indicates that bluewater ships are strictly more profitable along the Panama Canal route than arctic vessels. By assumption (3.3), an arctic ship is more profitable traveling through the Northwest Passage than a bluewater ship traveling through the Panama Canal,

[32] For the purposes of the model, this route will be henceforth referred to as "Panama Canal", but in principle any bluewater route could be used.

[33] Arctic vessels may either be too large to enter the Panama Canal (in which case their non-arctic profit is zero), or alternatively, because of their reinforced hull design, be less efficient under normal maritime conditions. Note that in practice there are many arctic class ships, and a variety of classification systems (Canadian Arctic Classification, and Lloyd's Insurance Classification, for example). The assumption in this model is that given the expected arctic conditions of the Northwest Passage in the future, the most desirable of these arctic designs is chosen for comparison.

which is motivated by the discussion of economies of scale in ship size in the previous section. Assumption (3.4) ranks the payoffs for the bluewater ships. In particular, a bluewater vessel will yield a positive profit when travelling through the Panama Canal, but cannot enter arctic waters. Hence, it receives a payoff of less than or equal to zero along the Northwest Passage route. From the above assumptions (3.3)-(3.4), the following condition must be true, which along with (3.1) and (3.2) completely ranks the possible vessel payoffs:

$$\pi_{NA} > \pi_{PB} \geq 0 \geq \pi_{NB} \tag{3.5}$$

Please note that π_{PA} is not ranked in (3.5) above since in theory it could assume a positive or negative value depending on the arctic ship technology employed. The only necessary assumptions concerning π_{PA} are (3.1) and (3.2).

A second "player", Nature (N), controls whether the passage opens (with probability p), or remains closed (with probability $1 - p$), where $1 \geq p \geq 0$. If the Northwest Passage opens at a given point, it remains open permanently; if it does not open at a given node, there is the possibility that it opens at Nature's following move, with the same probability.

As seen in Figure 1, the process consists of four periods, with the following sequence SL, N, SL, N.

3.1 Fleet Structure: Ordering Ships

As can be seen in Figure 1, at each SL node the shipping line must decide to order either an arctic or bluewater ship (A or B) prior to potential change in arctic conditions; only one ship may be ordered per SL node. Moreover, it takes one period for a ship to be built: the shipping line orders a ship at the SL node, and the ship becomes

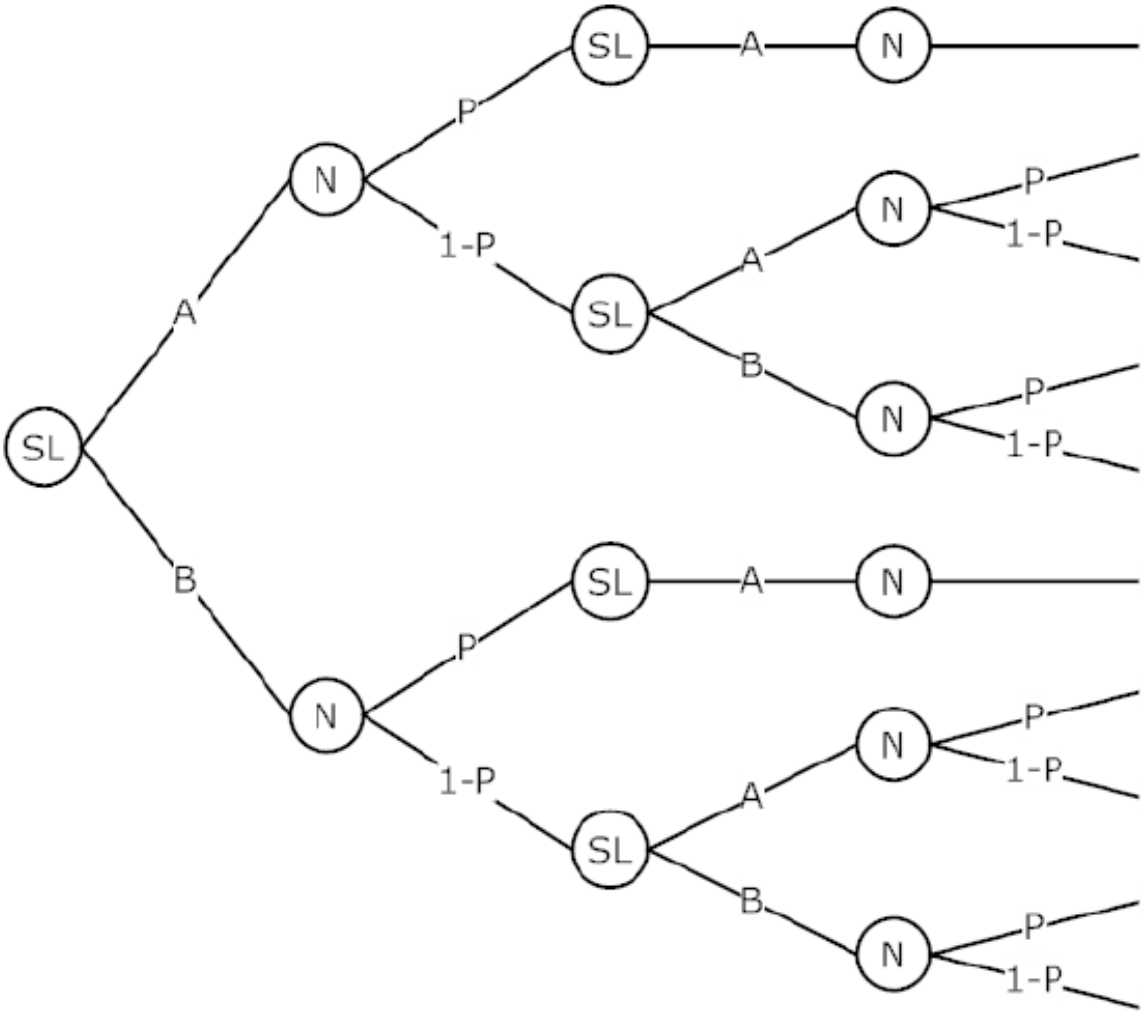

Figure 1: Decision Structure

operational (providing its corresponding payoff) at the following N node. Hence, a ship is ordered by the shipping line at the SL nodes and the existing fleet, including the newly arrived vessel, provide a payoff to the shipping line at each of the two N nodes.

Each ship has a finite lifespan, and can provide a maximum of 2 payoffs. That is, once a ship has provided two payoffs at two N nodes, it has fully depreciated. A 'new' ship is denoted $A(N)$ or $B(N)$ at its first N-node, and an 'old' ship is denoted $A(O)$ or $B(O)$ at its second N-node. At the end there will remain either an $A(N)$

or $B(N)$ ship, depending on which was recently ordered. The scrap value of a $B(N)$ vessel is normalized to zero, while the scrap value of an $A(N)$ vessel is given by a parameter, s, i.e. $s = A(N) - B(N)$.

3.2 Optimal Fleet Structure: Risk-Neutral Shipping Line

Second Ship Decision

Here we consider the optimal decision-making for a shipping line faced with the decision structure described above. To solve this decision, we must do so recursively. We begin by looking at the second ship order decision at the second SL node.
Regardless of whether A or B was chosen as the first vessel, if the passage opened at the first N-node then the decision is straightforward for the second ship: according to (3.5) the shipping line will select an A vessel as the second ship. We see this in Figure 2 where the second ship choice simplifies under an "open" Northwest Passage. What must be analyzed are the two remaining cases at the second SL node where the passage has not yet opened. Here we label them Case 1 and Case 2, as seen in Figure 2.

In the instance of Case 1, the shipping line is choosing its second vessel conditional on the passage not being open and having previously chosen an A ship. By contrast, with Case 2, the shipping line is choosing its second vessel conditional on the passage not being open and having previously chosen a B ship. In both cases, to determine the second ship selection criterion, we compare the expected value of choosing A with that of choosing B.

Rather than solving for a condition under both cases, it is straightforward to see that both will produce the same condition, namely (3.8) below. The model follows a Markov process: the second ship choice is independent of the initial first ship choice

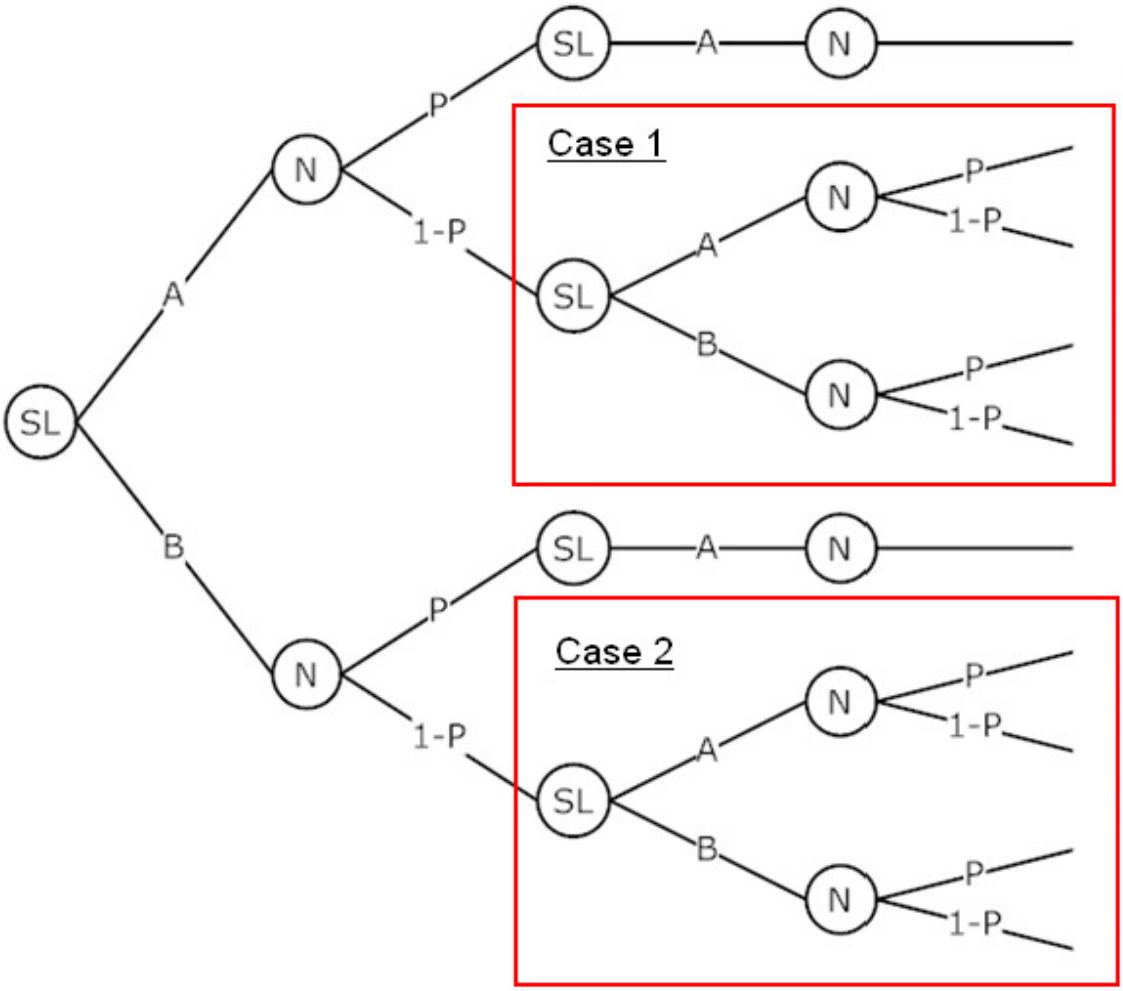

Figure 2: Second Ship Choice

and both cases may be analyzed together. For both Case 1 and Case 2, we calculate the expected value of choosing A and the expected value of choosing B. We denote these expected values as $E(A_2)$ and $E(B_2)$ respectively, where the subscript indicates that the ships are being considered for SL's second ship decision.

$$E(A_2) = p \cdot \pi_{NA} + (1-p)\pi_{PA} + s \tag{3.6}$$

$$E(B_2) = p \cdot \pi_{PB} + (1-p)\pi_{PB} = \pi_{PB} \tag{3.7}$$

These expressions simply yield:

$$E(A_2) - E(B_2) = p \cdot \pi_{NA} + (1-p)\pi_{PA} + s - \pi_{PB} \tag{3.8}$$

Condition (3.8) is the difference between the expected payoffs of selecting A_2 and B_2. If (3.8) is positive, then the expected payoff of A_2 exceeds B_2, and an A ship is chosen for the second ship; if (3.8) is negative, B_2 is chosen. Furthermore, without loss of generality and in accordance with assumptions (3.1)-(3.4) it is possible to normalize the payoffs such that $\pi_{PA} = 0$.[34] The condition reduces to:

$$E(A_2) - E(B_2) = p \cdot \pi_{NA} + s - \pi_{PB} \tag{3.9}$$

It can be seen clearly that this expression is decreasing in π_{PB}; as π_{PB} increases, holding other variables constant, it becomes more attractive to select a B vessel. Conversely, (3.9) is increasing in p, π_{NA}, and the scrap value, s. Increasing any of these variables will make it more attractive to select an A vessel, holding π_{PB} constant. We will further elaborate on these conclusions once the shipping line's decision has been completely solved.

First Ship Decision

Having solved for the second ship decision, one can now derive the first ship decision for the shipping line. There are two cases under which SL makes its first ship decision, and these cases are differentiated by whether A or B is selected in the second ship decision. For example, under the first case SL makes its first ship choice given that it chooses A_2. Alternatively, in the second case SL makes its first ship choice given that it chooses B_2. While the choice of the second ship is independent of the choice for the first ship, the converse is not true. SL's second ship decision will influence its first ship decision, which is demonstrated below.

[34] Doing so will allow for a clear solution to the first ship choice, to be discussed below, and will permit a more complete discussion of the model.

Assuming SL has chosen its second ship according to condition (3.9) above, SL takes the second ship choice as given for the first ship decision. For the purposes of the exposition below, it is assumed that SL selects A as its second ship.

Given this assumption, SL must compare two expected outcomes for its first ship decision. First, the shipping line must calculate the expected value of choosing A as the first ship and A as the second ship, given it has chosen A as the second ship. This will be denoted $E(A_1 + A_2|A_2)$ where the subscripts again represent whether a ship corresponds to the first or second ship decision. The second option SL must evaluate is the expected value of choosing B as the first ship and A the second ship, given it has chosen A as the second ship, correspondingly denoted $E(B_1 + A_2|A_2)$.

Since we have normalized the payoffs such that $\pi_{PA} = 0$, we may write these expressions as:

$$E(A_1 + A_2|A_2) = \delta \cdot s + p\left[1 + 2\delta(2-p)\right]\pi_{NA} \tag{3.10}$$

$$E(B_1 + A_2|A_2) = \delta \cdot s + (1+\delta)\pi_{PB} + p\delta(2-p)\pi_{NA} \tag{3.11}$$

For the complete derivation of these expressions, please see Appendix A. Note that a discount factor δ (where $\delta > 0$) appears in (3.10) and (3.11) above, and is used to discount the payoffs from both ships at the second N node.
Subtracting (3.11) from (3.10) yields the following:

$$E(A_1 + A_2|A_2) - E(B_1 + A_2|A_2) = p \cdot \pi_{NA} + p\delta(2-p)\pi_{NA} - (1+\delta)\pi_{PB} \tag{3.12}$$

Keeping in mind the second ship decision condition (3.9), we may rewrite (3.12) in the following form:

$$\mathrm{E}(\mathrm{A}_1 + A_2|A_2) - E(B_1 + A_2|A_2) = [p \cdot \pi_{NA} - \pi_{NA} + s] - [s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] \quad (3.13)$$

It can be seen that if the expression (3.13) is greater than zero SL would select an A ship during its first ship decision, while if (3.13) was less than 0 a B ship would be selected. Furthermore, the first bracketed term of expression (3.13) is identical to the condition (3.9) derived for the first ship choice. Therefore, it can be clearly seen under which conditions SL which select A or B in its first and second ship decisions. If (3.13) was positive and (3.9) was negative for example, SL would select A as its first ship and B as its second ship. A complete taxonomy of ship choices for the model can be created. The results are summarized below in Table 1.

It is important to mention that (3.13) was obtained by assuming that A was chosen as the second ship. However, the same condition is produced if one assumes that B is chosen as the second ship. The complete model exposition is found in **Appendix A**.

	$[p\pi_{NA} - \pi_{PB} + s] - [s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] > 0$	$[p\pi_{NA} - \pi_{PB} + s] - [s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] < 0$
$[p\pi_{NA} - \pi_{PB} + s] > 0$	$\mathbf{A_1, A_2}$	$\mathbf{B_1, A_2}$
$[p\pi_{NA} - \pi_{PB} + s] < 0$	$\mathbf{A_1, B_2}$	$\mathbf{B_1, B_2}$

Table 1: Ship Choice Taxonomy

A final important remark concerning these conditions is that SL would never choose B as its first ship and A as its second ship, provided that $p\pi_{NA}$ is greater than π_{PB}.

In other words, provided that the expected payoff of an arctic ship is greater than the certain payoff of a bluewater ship, choosing A as the second ship implies that A is also chosen as the first ship. This intuitive result is shown in **Appendix A**.

3.3 Comparative Statics

Probability of the Northwest Passage Opening (p)

Having solved for the conditions (3.9) and (3.13) above, one can assess the impact of parameter changes on SL ship ordering decisions. To make clear their relationship to the first and second ship decisions, we relabel the first ship decision condition (3.13) as $D1(\cdot)$ and the second ship decision condition (3.9) as $D2(\cdot)$, and then differentiate with respect to p to obtain:

$$\frac{dD1(\cdot)}{dp} = \pi_{NA}(1 + 2\delta - 2p\delta) \tag{3.14}$$

$$\frac{dD2(\cdot)}{dp} = \pi_{NA} \tag{3.15}$$

It can be clearly seen that both expressions are increasing in p. Since $1 \geq p \geq 0$ and $\pi_{NA} > 0$ by assumption (3.5), the derivative (3.14) is increasing and the first ship decision condition is increasing in p. Note that (3.14) depends on the values of π_{NA} , p and the discount rate. From (3.15), the second ship decision condition is also clearly increasing in p. These are straightforward results; the more likely the Northwest Passage is to open, the higher the expected profit of choosing A-vessels for both the first and second ship decisions of the model.

A-Vessel Profit, Northwest Passage (π_{NA}) *and B-Vessel Profit, Panama Canal* (π_{NA})

We may also differentiate with respect to π_{NA} and π_{PB}. The first order conditions (3.16) and (3.17) are taken with respect to π_{NA}, while (3.18) and (3.19) are taken with respect to π_{PB}.

$$\frac{dD1(\cdot)}{d\pi_{NA}} = (p + 2p\delta - p^2\delta) \tag{3.16}$$

$$\frac{dD2(\cdot)}{d\pi_{NA}} = p \tag{3.17}$$

From (3.16) and (3.17), one can see that both ship decisions are increasing in π_{NA}. Accordingly, an increase in the profit of an arctic ship will increase the incentive for SL to acquire one.

$$\frac{dD1(\cdot)}{d\pi_{PB}} = -1 - \delta \tag{3.18}$$

$$\frac{dD2(\cdot)}{d\pi_{PB}} = -1 \tag{3.19}$$

From (3.18) and (3.19), both ship decisions are decreasing in π_{PB}; as bluewater vessels become more profitable, it becomes more attractive to select a B ship.

A-Vessel Scrap Value (s)

$$\frac{dD1(\cdot)}{ds} = 0 \tag{3.20}$$

$$\frac{dD2(\cdot)}{ds} = 1 \tag{3.21}$$

From (3.19), the scrap value of an A vessel does not affect the first ship decision as the first ship will have depreciated fully. However, the second ship decision is increasing in the scrap value and an increase in s will make the shipping line more likely to select an A ship.

Discount Rate (δ)

The discount rate is only applicable to the first ship decision and the derivative is given by (3.22) below. Note that the effect of a change in the discount rate on the first ship decision is ambiguous; the term $(2p - p^2) > 0$, and $\frac{\pi_{NA}}{\pi_{PB}} > 1$ by assumption

in the model. However, the product of these terms must be greater than one in order for an increase in the discount rate to making choosing A more favourable in the first ship decision. If the product of the terms is less than one, then an increase in the discount rate will make B more favourable in the first ship decision.

$$\frac{dD1(\cdot)}{d\delta} = (2p - p^2) \cdot \frac{\pi_{NA}}{\pi_{PB}} - 1 \tag{3.22}$$

3.4 A Need for Investment in the North

The above model illustrates that as the probability of the passage opening and the profit of arctic ships increase over time, a shipping line will face increased incentive to order arctic vessels for its fleet. The government may be able to raise the value of π_{NA} through investment in arctic ports, search and rescue capabilities, navigational aids and other services to facilitate shipping through the Northwest Passage. As shipping companies commission new and improved ship designs to accomodate the opportunities of a warming arctic, we might similarly expect π_{NA} to increase.[35]

While investment is likely to provide incentive for companies to consider arctic shipping through the Northwest Passage in the long-run, it is not the only case for government investment. Equally important is the fact that increased vessel traffic in the north will result in an increased demand for security; with increased traffic, the Northwest Passage will become more vulnerable to threats such as terrorism and illegal immigration. Vessel monitoring (including the capability to monitor foreign submarines) and Coast Guard/Navy arctic capabilities will become necessary to ensure that Canada is able to adequately patrol a Northwest Passage accessible to foreign vessels. Environmental security will be very important - Canada will need the capability to adequately monitor and deter vessels posing a threat to the arctic marine environment.

[35]For example, for a discussion of Russian investment in arctic ship technologies, see: Tinsley, D. (2009, January 22), Arctic gold rush drives evolution of ice vessels, Lloyd's List.

The remainder of this paper provides a structure for Canada to examine its investment decision. Compounding the challenge for Canada is the fact that its sovereignty over the Northwest Passage is disputed by the United States: the interaction of these legal and political circumstances must be considered by Canada.

4 The Northwest Passage and Arctic Sovereignty

"Arctic sovereignty" has become an umbrella term used to encompass several international arctic disputes involving Canada. These individual disputes are largely independent of one another, presenting distinct challenges and requiring specific approaches.[36] "Sovereignty" is a nebulous term, as it varies in the context of these individual issues in addition to encompassing legal, social, political and economic dimensions.

In the case of the Northwest Passage, there is no international dispute regarding Canada's sovereignty over its land. Indeed, the entire Arctic archipelago is considered Canadian territory.[37] What is rather at stake is the extent to which Canada has the right to exercise control over the waters of the Northwest Passage - whether the waters of the Northwest Passage fall within the domain of Canadian or international law. In particular, Canada asserts that the Northwest Passage constitutes "historic internal waters", while the United States and European Union contend that it is an international straight; these are the only two possible legal regimes for the Passage under international law.[38] The heart of the issue is therefore whether Canada is able

[36]For example, international disputes include the Northwest Passage, the debate between Canada and the US over the maritime boundary between Alaska and the Yukon, the continental shelf debate between Canada, the US and Russia, and the Hans Island dispute between Canada and Denmark. For a concise survey of these disputes and others, please see: Rob Huebert. "Northern Interests and Canada Foreign Policy", available at: `http://www.cdfai.org/PDF/Northern%20Interests%20and%20Canadian%20Foreign%20Policy.pdf`

[37]The only land issue Canada faces is the dispute between Canada and Dennmark over Hans Island, a small island between Greenland and Ellesmere Island.

[38]Andrea Charron."The Northwest Passage in Context", Canadian Military Journal, Winter 2005-

to unilaterally legislate policy to regulate Canadians and foreigners in the Northwest Passage. The legal framework for oceans, within which both positions are argued, is a product of the 1982 United Nations Convention on the Law of the Sea (UNCLOS), and is also a product of international law.

In order to place the dispute in proper context it is valuable to summarize the legal regimes for the oceans. These regimes define the territorial sea as that which encompasses the area 12 miles from the coast, "usually from the low water mark".[39] The state's sovereignty over its territorial sea is similar to its land territory, with one exception - there is a right of *innocent passage*.[40] The right of innocent passage dictates that a vessel "must not act in a way that is prejudicial to the peace, good order or security of the coastal state".[41] Accordingly, submarines must not navigate submerged, and while the coastal state has the option to introduce legislation related to its territorial sea, including environmental and marine pollution legislation, it cannot ultimately deny the right of innocent passage.[42] By contrast, any waters inland of the territorial sea are considered internal waters and are "subject to the full sovereignty of the coastal state with no associated right of innocent passage through them".[43]

If the waters of a territorial sea are deemed an international straight, however, there is a right of *transit passage* according to the 1982 UNCLOS.[44] The right of transit passage differs from the right of innocent passage. In contrast to innocent passage, transit passage permits submarines to travel submerged, and pollution legislation must agree with "international standards", set either through agreements between

2006, p.42. Henceforth referred to as Charron (2006)

[39]Ibid, p.4

[40]Ibid.

[41]Ibid, p.5

[42]Ibid, p.5

[43]Ibid.

[44]Donald McRae."Arctic Sovereignty? What is at Stake?" Behind the Headlines: Canadian International Affairs, Volume 64 Number 1, 2007, p.5. Henceforth known as McRae (2007).

states, or through treaties arranged via the International Maritime Organization.[45] Finally, the right of overflight exists for an international straight; other nations are permitted to fly aircraft over an international straight.

While the above discussion only highlights the key points of the legal framework for the oceans, it makes clear that depending on whether the Northwest Passage is deemed internal waters or an international straight Canada will have different legal rights. The difference between these rights when Canada is and is not sovereign - and the difference in policy options afforded by each set of rights - represents, in part, the strategic value of sovereignty to Canada. We now turn to discuss the Canadian and American arguments. The issue of what the Canadian policy framework might look like, with and without sovereignty will be subsequently dealt with in separate section.

4.1 The Canadian Legal Position

There are several publications which are worthy of investigation describing in detail the historical evolution of Canada's claim to sovereignty over the Northwest Passage.[46] What are of interest to the policy maker, however, are the modern legal arguments justifying Canada's claim to the Passage.

The modern claim for sovereignty over the Passage stems from the *Territorial Sea Geographical Order* of 1986 which encapsulated the Northwest Passage through straight geographical baselines.[47] Rather than following the outline of a country's land mass along the low-water mark of its 12-mile territorial sea as is done with baselines, "straight baselines" can be applied in circumstances where the coastline is very indented or "jagged", and/or where there are islands off the coast which complicate

[45]Ibid, p.5. In the Canadian case of the Northwest Passage, however, additional environmental legislation would be possible through Article 234 of UNCLOS, which will be discussed shortly.

[46]For example, Charron (2006) and Byers and Lalonde both provide engaging discussion.

[47]Charron (2006), p.43

following the low-water mark.[48] Using the straight baseline method, straight lines are drawn from the outer edge of a coast to an island, or from island to island, and the water enclosed behind the baselines is considered internal waters.[49] This method of calculation has the end result of increasing the area of water deemed internal.[50] Figure 3 depicts graphically how the straight baseline method may be used.[51] In the case of the Northwest Passage, the straight baseline method is sufficient for designating the Passage as internal waters.

The enclosure of the Northwest Passage by straight baselines is not an arbitrary act of the Canadian government - it is supported by the International Court of Justice (ICJ) through the 1951 *Fisheries Case* between the United Kingdom and Norway. In brief, the ICJ ruled that the straight baseline method was a legally acceptable methodology for the determination of internal waters along fragmented coastlines, and it also recognized the concept of historic title to coastal waters.[52] The same approach has been adopted by many states, and is endorsed through Article 7 of UNCLOS.[53]

The recognition of historic title in the 1951 *Fisheries Case* is important. From the Canadian perspective, the validity of straight baselines is reinforced via one of Canada's traditional arguments in favour of sovereignty over the Passage - historic usage. Historic use and occupancy of the sea ice by Inuit "helps to justify, not only Canada's straight baseline system as a whole, but also individual baselines which may depart somewhat from the geographical criteria established under international law."[54] Recognition of this fact is further cemented through the *Nunavut Land Claims Agreement* of 1993 which indicated that, "Canada's sovereignty over the waters of the

[48]MacRae (2007), p. 10
[49]Charron (2006), p.44
[50]Ibid.
[51]Government of Canada,"The Law of the Sea Convention", 1993.
Available at: `http://dsp-psd.tpsgc.gc.ca/Collection-R/LoPBdP/BP/bp322-e.htm`
[52]Charron (2006), p.43
[53]MacRae (2007), p.11
[54]Byers and Lalonde, p.13

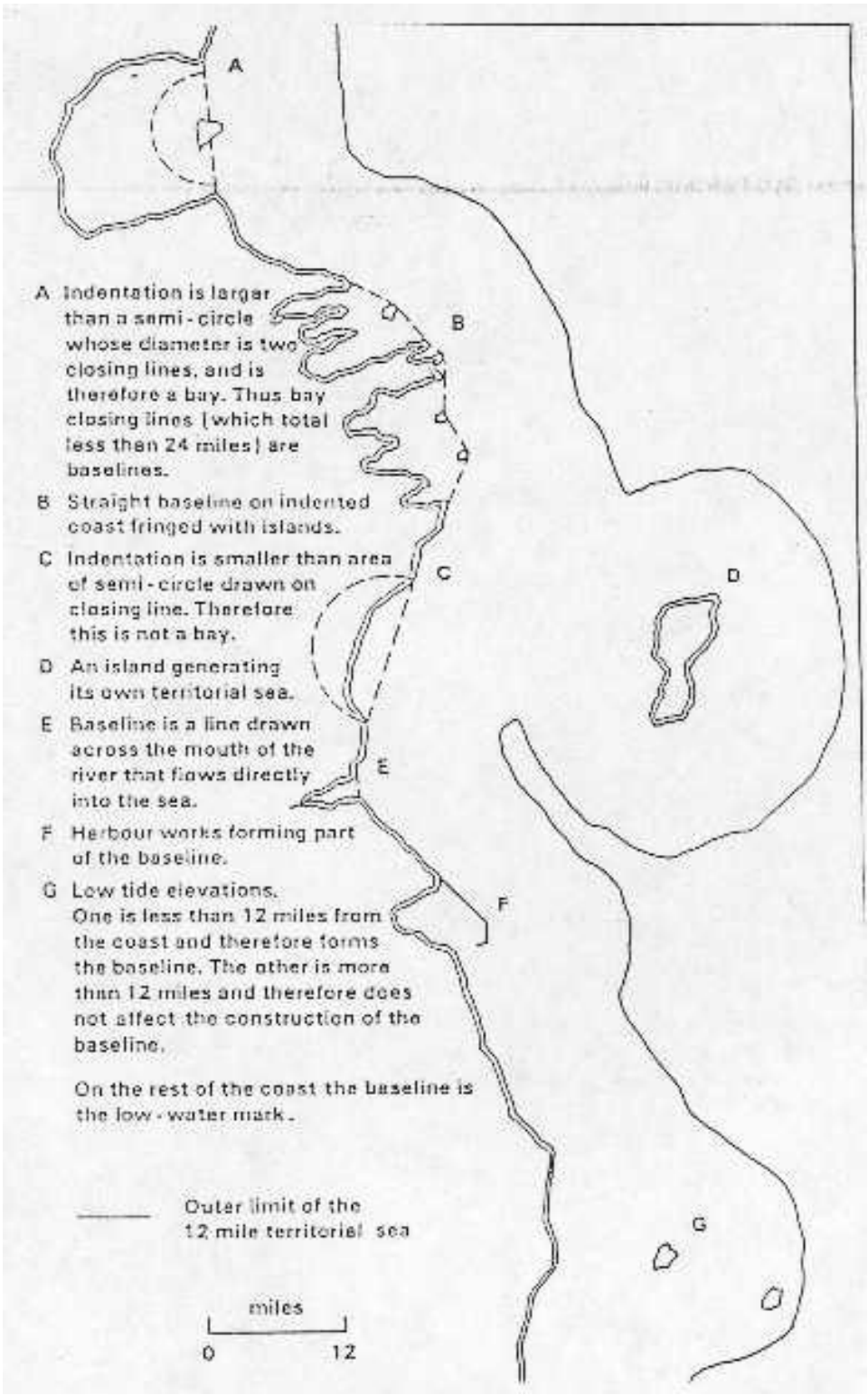

Figure 3: Baseline Examples

Arctic archipelago is supported by Inuit use and occupancy."[55]

4.2 The American Legal Position

While Canada's use of straight baselines is supported by legal precedent in the ICJ, it is nevertheless disputed by some nations - chiefly the United States - who are concerned that Canada's sovereignty over the Northwest Passage may set a precedent which reduces their freedom of navigation in other international straights. The US position - that the Northwest Passage constitutes an international straight - represents the challenge to Canada's sovereignty. In order for the Passage to be deemed an international straight, there are two criteria that must be satisfied: a geographic and a functional test.[56] The geographic test is straightforward: in order for a waterway to be considered an international straight, it must join two areas of high seas. Since the Northwest Passage joins the waters of the Labrador Sea with those of the Beaufort Sea, thereby connecting the Atlantic and Pacific Oceans, there is no contest over whether the Northwest Passage satisfies the geographic test - it is clearly satisfied.

Where the ambiguity arises is whether the functional test is met. This is essentially a test based on usage; to pass the functional test, a waterway must be "used for international navigation".[57] The wording is derived from the 1949 ICJ *Corfu Channel Case* between the United Kingdom and Romania.[58] In this case, the ICJ concluded that Corfu Channel was an international straight based on its relatively small amount of international maritime traffic.[59] According to most legal experts, the traffic in the Northwest Passage has not yet met the functional criterion; there have been roughly one hundred surface transits in the past one hundred years.[60] The caveat with this commonly held view is that very little is known about the transit of foreign

[55]Ibid.
[56]Charron (2006), p.44.
[57]MacRae (2007), p.14
[58]Charron (2006), p.45
[59]Ibid. Nevertheless, there was in one recorded year almost 3000 vessels using the Channel.
[60]Charron (2006), p.45 and MacRae (2007), p.15

submarines in the Northwest Passage, and if it could be demonstrated that this traffic is significant, it could undermine the legal position of Canada.[61]

4.3 No Legal Solution?

As discussed, both the US and Canada have positions supported by case precedent from the International Court of Justice and therefore set in international law. As a result, many have concluded that the question of sovereignty is unlikely to be resolved legally.[62] Government policies and multilaterial negotiation are therefore more useful approaches.

If Canada were challenged, however, the case would go to trial in the International Court of Justice. McRae (2007) notes that when Canada implemented the straight baselines method, it altered its acceptance to the jurisdiction of the International Court of Justice in order to allow challenges from nations without its consent.[63] Therefore, other nations such as the United Kingdom could challenge Canada on the issue of the Northwest Passage and Canada would go to trial. The United States, however, no longer accepts the compulsory jurisdiction of the ICJ: if the United States were to challenge Canada, Canada would have a choice whether to go to trial.[64]

The most important conclusion arriving from this discussion, however, is that the relative strength of the Canadian case for sovereignty is subject to changing environmental conditions and levels of maritime traffic in the Northwest Passage. Currently, Canada's position is relatively strong, due to the lack of known transits through the Passage, and as stated, the general consensus is that the functional criterion has not yet been met. However, if the arctic warms in the future and becomes seasonally ice-free, vessel traffic in the Passage will likely increase. If this were to occur without the

[61] McRae (2007), p.15
[62] Charron (2006), p.47
[63] McRae (2007), p.12
[64] Ibid.

appropriate policy and infrastructure in place, Canada would be much more likely to lose its claim to the Passage. McRae summarizes this reality succinctly: "The challenge for Canada is to ensure that all transits of the Northwest Passage are with its knowledge and consent."[65]

The Russian Example: The Case of the Northern Sea Route

When considering Canadian policy, it is also valuable to keep in mind the Russian approach to the Northern Sea Route. The United States similarly maintains that the Northern Sea Route, like the Northwest Passage, is international waters.[66] Russia has, however, aggressively promoted these waters for commercial shipping. Since 1990, it has undergone investment in infrastructure and offered key services such as ice-breaking and navigational aid.[67] Consequently, Russia is able to levy transit fees of up to US $500,000 on vessels choosing to use the route.[68] This investment and promotion has arguably improved Russia's claim to sovereignty over the Northern Sea Route.[69]

4.4 The Value of Sovereignty to Canada

Having established the legal debate and two legal regimes which the Northwest Passage could fall under, it is worthwhile to introduce the reasons sovereignty may be important to Canada. While media and politicians are quick to appeal to Canadians' sense of nationalism, what matters most are the differences in policy options under the two legal regimes.

The first difference relates to Canada's ability to enact pollution regulations for vessels if the Northwest Passage were an international straight. According to McRae

[65] McRae (2007), p.17

[66] Previously referred to as the Northeast Passage, the Northern Sea Route is a shipping lane along the Russian coasts from the Atlantic to Pacific Oceans.

[67] Charron (2006), p. 45

[68] Byers and Lalonde, p.3

[69] Charron (2006), p.45

there would be "little impact on Canada's legal authority to regulate commercial shipping."[70] Article 234 of UNCLOS - which applies to ice-covered areas - would provide the necessary authority for Canada to enact pollution legislation for commercial vessels:

> Coastal states have the right to adopt and enforce non-discriminatory laws and regulations for the prevention, reduction and control of marine pollution from vessels in ice-covered areas within the limits of the exclusive economic zone, where particularly severe climactic conditions and the presence of the ice covering such areas for most of the year creates obstructions or exceptional hazards to navigation, and pollution of the marine environment could cause major harm to or irreversible disturbance to the ecological balance. Such laws and regulations shall have due regard to navigation and the protection and preservation of the marine environment based on the best available scientific evidence.[71]

There nevertheless remain potential complications with this legislation. In an international straight, Canada would not be able to place pollution regulations on foreign government vessels, including foreign military vessels, and would have to rely on bilateral and multilateral agreements to do so.[72] McRae further notes that in the future, the Northwest Passage will be ice-covered on a decreasing annual basis. This may make the Article 234 precarious to rely on in the long-run.[73]

From another perspective, McRae's statement that commercial shipping regulation would remain largely unaffected is not strictly correct. If Canada did not have sovereignty over the Passage, it would have no authority to levy transit fees on vessels. As with similar Pigovian taxation mechanisms, such fees are an important policy instrument to treat a negative externality - in this case marine pollution - and also generate revenue. At present it is unknown whether future traffic through the Passage could represent a significant revenue stream, but Canada would forego

[70] McRae (2007), 18

[71] The United Nations Convention on the Law of the Sea, Article 234. Available at: http://www.un.org/Depts/los/convention-agreements/texts/unclos/UNCLOS-TOC.htm

[72] McRae (2007), p.18

[73] McRae (2007), p.19

this option should the Passage become an international straight. This issue has not received mention in the policy discussion, and warrants attention.

If the Northwest Passage becomes an international straight there may also be increased security concerns, for reasons outlined in the previous discussion of the two regimes: foreign submarines would have the right to travel submerged, and foreign aircraft would be permitted to fly over the Northwest Passage. Both issues present concerns for North American continental security. Importantly, these issues also hint at the fact that any strategic game between Canada and the U.S. over the Northwest Passage will not be a zero-sum game; the United States will forego some security if the Passage becomes an international straight.[74]

Related to both environmental and more traditional security concerns, Canadian law may prove a more effective jurisdiction than international law. Byers and Lalonde (2006) argue that, "National jurisdiction, where available, should always be seized upon as the optimum - though not necessarily exclusive - avenue for environmental protection."[75] Moreover, the Canadian legal system's criminal, customs and immigration laws may provide more security than the "looser constraints" of international law.[76]

5 Canada's Investment Decision: A Game-Theoretic Approach

Here we present a simultaneous game between Canada and the United States, both of whom are concerned about the legal regime of the Northwest Passage. When deciding to invest in the Passage, Canada must choose between two investment strategies: a high level of investment and a low level of investment. By contrast, the United States

[74]This issue is explored in the next section of the paper.
[75]Byers and Lalonde, p.21
[76]Michael Byers."Unfrozen Sea: Sailing the Northwest Passage", Policy Options, p. 33

must choose to either acknowledge Canada's sovereignty claim or maintain that the passage is an international straight. The United States undergoes no investment if it chooses to acknowledge Canadian sovereignty; if it argues that the passage is an international straight, it will undergo some fixed level of investment to support its position.

A key feature of the game is that the United States' policy choice will unilaterally determine the legal regime of the Northwest Passage (i.e., if the US argues that the Passage is an international straight, Canada will lose its sovereignty claim). While this may appear restrictive, it is the most intuitive modeling approach. As mentioned in the preceding legal discussion, there would be no guarantee that Canada, if challenged, would win its case in the International Court of Justice. Any dispute between Canada and the United States on this issue would likely be resolved politically, and it would be a costly diplomatic strategy for Canada to aggressively challenge the United States. Charron (2007) notes, for example, that what "Canada cannot afford is a standoff with the US - digging its heels in to demand sovereignty."[77] What Canada's legal case for sovereignty does provide is the possibility that Canada might undergo investment to secure a sovereign regime consistent with Canadian and American preferences.

A second important feature of the game concerns the arrangement between Canada and the United States should the Northwest Passage become an international straight. If the legal regime becomes an international straight, both countries in the game engage in a bilateral agreement to manage the Northwest Passage. Given American concerns with North American continental security, this is the most appropriate alternative in the absence of Canadian sovereignty and is consistent with the policy literature.[78]

[77] Andrea Charron. "The True North Stronger and Freeer with Help", Defence Requirements for Canada's Arctic, Vimy Paper (Conference of Defence Associations Institute), 2007

[78] For example, see Coates (2008).

At this point, it is instructive to outline the game explicitly:

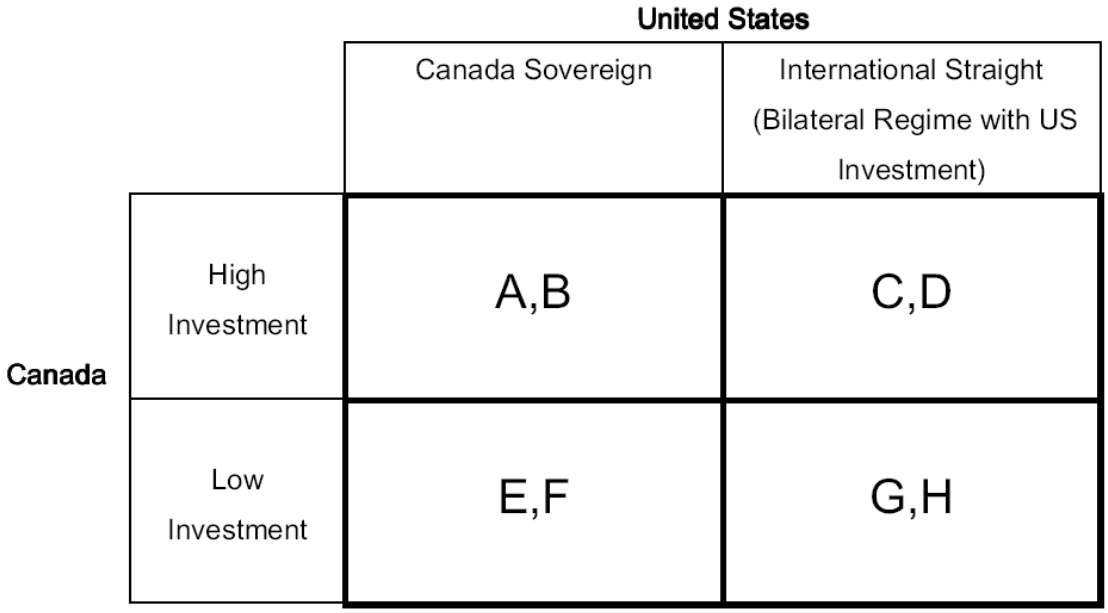

Figure 4: Payoff Matrix

Figure 4 presents the payoff matrix for the game, with the United States as the row player, and Canada as the column player:

Defining Payoffs: Canada

A, E, C and G in Figure 4 represent the payoffs to Canada. Each of these payoffs is summarized in Table 2.

Table 2: Canada Payoffs

A	$p\psi - I_{CAN,H}$
E	$p\gamma - I_{CAN,L}$
C	$p\theta\alpha - I_{CAN,H} + B_{US}$
G	$p(1-\theta)\alpha - I_{CAN,L} + B_{US}$

A and E represent the expected net benefits to Canada under high- and low- investment sovereign regimes. As in the previous stochastic control model, p is the

probability of the Northwest Passage opening, where $1 \geq p \geq 0$; note that for simplicity, the payoffs from investment are assumed to be entirely dependent on the Passage opening. The two levels of investment are denoted by $I_{CAN,H}$ and $I_{CAN,L}$. Furthermore, each state contains some benefit, ψ and γ, where $\psi > \gamma \geq 0$.

There are several potential sources for revenue if Canada were to have sovereignty over the Northwest Passage. Government investment in infrastructure, including port facilities, search and rescue, etc. would allow the government to provide services at set fees to vessels traveling through the Passage. Canada would also have the authority to levy transit fees on vessels, as the Russians are presently pursuing with their Northern Passage.

In the case of C and G, Canada is participating in a bilateral regime with the United States, and the Passage is an international straight. Although Canada would no longer be able to generate transit fees from vessels traveling through the Passage, the bilateral regime may nevertheless be able to provide some local services to transiting vessels generating revenue α, where $\alpha \geq 0$. This revenue is split between Canada and the United States by the exogeneous parameter θ, where $1 \geq \theta > (1 - \theta)$. Canada's share of α between the two payoffs depends on its level of investment: if Canada chooses high investment, it will receive $\theta\alpha$, and $(1 - \theta)\alpha$ otherwise. Finally, in both states, Canada will receive a spillover benefit from the investment undertaken by the United States, B_{US}, since some of the US investment will be allocated to defence spending, a pure public good.[79]

Defining Payoffs: United States

The reality for the United States is that Canadian sovereignty over the Northwest Passage is the strongest legal regime for North American security. As discussed ear-

[79]We might also expect spillovers from US investment in other goods, such as Canadian arctic ports.

Table 3: United States Payoffs

B	$p(-L+S+B_{CAN})$
F	$p(-L+S)$
D	$p[(1-\theta)\alpha+L-S+B_{CAN}]-I_{US}$
H	$p(\theta\alpha+L-S)-I_{US}$

lier, if the Passage were instead an international straight, the right of transit passage would exist for foreign government vessels, submarines would be permitted to travel through the Passage submerged, and the right of overflight would exist for foreign aircraft. Accordingly, additional investment in security would be necessary to address these concerns if the Passage was an international straight. For the United States, this cost is explicitly represented by S.

At the same time, the US faces a cost in acknowledging Canada's sovereignty. By affirming Canadian sovereignty, the US may produce a precedent that impedes their passage in other international straights around the world; freedom of navigation is an important policy issue for the United States. To capture this concern, L represents the legal costs which would arise should the United States face challenges to their freedom of navigation as a result of a Canadian precedent.

For payoffs B and F under Canadian sovereignty, the United States therefore weighs the opposing concerns of L and S. In the case of B, the US receives a spillover as the result of Canada pursuing high investment, B_{CAN}, where $B_{CAN} \geq 0$; this is the additional spillover above what occur in the case where Canada undertakes low investment.

In the case of payoffs D and H, the United States receives a share of α depending on Canada's choice to invest high or low. For both expected net benefits, S and L are again traded-off, although in the opposite direction. The US will continue to receive

the additional spillover, B_{Can}, resulting from a high-level of Canadian investment.

Nash Equilibria

With the payoffs defined, it is possible to characterize the Nash Equilibria of interest in the game:

Lemma 1 (United States).

Let $\overline{\alpha} = \frac{2p(S-L)+I_{US}}{p(1-\theta)}$ and $\underline{\alpha} = \frac{2p(S-L)+I_{US}}{p\theta}$, where $\overline{\alpha} > \underline{\alpha}$ since $\theta > (1-\theta)$.

If $\alpha \leq \underline{\alpha}$ then "Canada Sovereign" is a dominant strategy for the United States.

If $\alpha \geq \overline{\alpha}$ then "International Straight" is a dominant strategy for the United States.

If $\overline{\alpha} > \alpha > \underline{\alpha}$ then the United States' strategy is contingent on Canada's strategy.

Proof. See Appendix B.

Lemma 2 (Canada).

Let $I_{CAN,H} - I_{CAN,L} = \Delta I$

Assuming that $(\psi - \gamma) > \alpha(2\theta - 1)$[80]:

If $p\alpha(2\theta - 1) \geq \Delta I$ then "High Investment" is a dominant strategy for Canada.

If $p(\psi - \gamma) \leq \Delta I$ then "Low Investment" is a dominant strategy for Canada.

If $p(\psi - \gamma) > \Delta I > p\alpha(2\theta - 1)$ then Canada's strategy is contingent on the strategy of the U.S.

Proof. See Appendix B.

Proposition 1 (Nash Equilibria).

Following from Lemmata 1 and 2:

If $\alpha \leq \underline{\alpha}$ and $p\alpha(2\theta - 1) \geq \Delta I$ then ("High Investment", "Canada Sovereign") is the Nash Equilibrium.

[80]This assumption is necessary in order to appropriately rank Canada's strategies. The difference in benefits under high and low investment sovereignty outcomes (the LHS of the inequality) must be greater than the difference in the share of benefits Canada would receive from high and low investment under a bilateral regime (the RHS of the inequality). This is realistic - the notion that the LHS is relatively large is an important claim motivating the discussion of this policy issue.

If $\alpha \leq \underline{\alpha}$ and $p(\psi - \gamma) \leq \Delta I$ then ("Low Investment", "Canada Sovereign") is the Nash Equilibrium.
If $\alpha \geq \overline{\alpha}$ and $p\alpha(2\theta - 1) \geq \Delta I$ then ("High Investment", "International Straight") is the Nash Equilibrium.
If $\alpha \geq \overline{\alpha}$ and $p(\psi - \gamma) \leq \Delta I$ then ("Low Investment", "International Straight") is the Nash Equilibrium.
If $\overline{\alpha} > \alpha > \underline{\alpha}$ and $p(\psi - \gamma) > \Delta I > p\alpha(2\theta - 1)$ then ("Low Investment", "International Straight") and ("High Investment", "Canada Sovereign") are the two Nash Equilibria of the game.

With respect to *Lemma 1*, note that the values of $\overline{\alpha}$ and $\underline{\alpha}$ depend on parameters in the United States' payoffs' - these can be easily compared to the value of the parameter α. For example, it can be clearly seen that $\overline{\alpha}$ and $\underline{\alpha}$ are decreasing in L. If L were sufficiently large, both $\overline{\alpha}$ and $\underline{\alpha}$ would be small enough such that $\alpha \geq \overline{\alpha}$. This would result in "International Straight" being a dominant strategy for the United States. Conversely, $\overline{\alpha}$ and $\underline{\alpha}$ are increasing in S and I_{US}. An increase in either of these variables makes it less likely that $\alpha \geq \overline{\alpha}$ and therefore more likely that "Canada Sovereign" becomes a dominant strategy. Since both of these parameters are costs that the United States must face in order to achieve the bilateral regime, this is an intuitive result. Finally, note that the parameter θ, which is an exogenous benefit sharing parameter for the bilateral regime, will determine the relative difference in the values of $\overline{\alpha}$ and $\underline{\alpha}$.

Lemma 2 provides similarly intuitive conditions for Canada. Canada's incremental investment (i.e., the difference between high and low investment), ΔI is compared to the difference in the expected benefits of high and low investment that Canada would receive under sovereignty, $p(\psi - \gamma)$ and under an international straight, $p\alpha(2\theta - 1)$. For example, if $p(\psi - \gamma)$ was very small such that $p(\psi - \gamma) \leq \Delta I$, "Low Investment"

would become a dominant strategy for Canada.

Proposition 1 follows directly from *Lemma 1* and *Lemma 2* and provides the Nash Equilibria for the game. The most interesting case is arguably where there are no dominant strategies and two Nash Equilibria, i.e. when $p(\psi - \gamma) > \Delta I > p\alpha(2\theta - 1)$ and $\overline{\alpha} > \alpha > \underline{\alpha}$. This will now be discussed.

5.1 Application to Government Policy

One useful application of this game is that it is sufficiently flexible to catalogue several views on the Northwest Passage in the policy literature. Insofar as many of these competing policy perspectives are predicated upon the belief of specific parameter(s) (and often omitting assumptions about the other parameters of the game), it is helpful to compare them. For instance, consider the view espoused by Coates et al.(2008):

> In the final analysis, Canada will not be able to overcome American designs on the Arctic. We can pontificate endlessly, but the reality is that United States has the will and resources to secure access to the Northwest Passage. Americans' long-standing belief in the need for their Navy to have unfettered rights to navigate international straights around the world means that they will not concede on the status of the Passage for fear that it will set a precedent elsewhere. Canada can head off an unseemly contretemps by working with the United States to develop a shared strategy for the control, regulation, and use of the Northwest Passage.[81]

In the context of the game presented, Coates et al. would argue that L is sufficiently high to ensure that $\alpha > \overline{\alpha}$ and that playing "International Straight" is a dominant strategy for the United States; Canada cannot hope to invest and obtain sovereignty. While this is indeed possible, there remains considerable disagreement. An alternative perspective is held by Byers (2007) who sees the additional security benefits offered by Canadian sovereignty to the United States (i.e., S) as much larger relative to L:

[81] K.S. Coates, P.W. Lackenbauer, W.R. Morrison and G. Poelzer, Arctic Front: Defending Canada in the Far North, 2008, p.203

> From Washington's perspective, the Canadian claim threatened to create an inconvenient precedent for straights and channels elsewhere. Today, Washington is more concerned about terrorists sneaking into North America, or rogue states using the oceans to transport WMD. And these challenges would best be addressed through a domestic legal system's criminal, customs and immigration laws, rather than the much looser constraints of international law...The Canadian government should seize the initiative by offering to provide open access US government vessels, facilitate shipping by reputable companies, and invest in the equipment necessary to police the passage on a year-round basis - in return for the United States recognizing Canada's claim.[82]

Byers' view is compatible with the values of ΔI and α in the intermediate range in the game, where there are two possible Nash Equilibria: "Low Investment, International Straight" and "High Investment, Canada Sovereign". And although the game modeled is simultaneous, the intuition is indeed that if Canada could somehow commit to a high level of investment, it may be able to 'steer' the game to the "High Investment, Canada Sovereign" Nash Equilibrium.

Canadian speculation on the position of the United States has been spurred by signals from the United States. In March 2005, the US ambassador at the time, Paul Celucci, suggested that it would be in the interest of US national security to have Canada control the Northwest Passage. Celluci commented that he had asked the State Department to take "a serious look at our longstanding policy".[83] Moreover, President Bush indicated in his August 2007 Montebello statement that he supported Canada's investments "to exercise its sovereignty".[84] Both of these comments seem to recognize, at least implicitly, that the United States would not object to Canada exercising sovereign authority over the Passage despite an official policy position to the contrary.

[82]Byers, p.33

[83]Byers, p.33

[84]Donald McRae."Rethinking the Arctic: A new agenda for Canada and the United States", Canada-Us Project Conference 2008, p.14-6

In early January 2009, however, the Bush administration issued a new arctic policy directive which reasserted the American position that the Northwest Passage is an international straight. From the perspective of the game presented, such a policy position is again consistent with "International Straight" being a dominant strategy for the United States, or alternatively with the fact that ΔI and α are in the intermediate range - to date, Canada has essentially invested "low". As a final point on this issue, it is interesting to note that this directive was removed from the White House website within minutes of President Obama's inauguration. Moving forward, Canada's ability to negotiate will depend on the willingness of this new administration.

5.2 A Need to Directly Consider the Sovereignty Issue

> *"The issue of the Northwest Passage cannot be avoided. It's time for both Canada and the United States to stop the shenanigans - and negotiate a comprehensive agreement on shipping in the North." - Michael Byers*

Due to the uncertainty surrounding both the legal status of the Passage and the policy position of the United States, some have argued that the government's preoccupation with the affirmation of sovereignty may be hindering its ability to effect meaningful policy. Charron (2005) creates a distinction between two approaches to the issue of the Northwest Passage: "sovereignty first and foremost" and secondly, "sovereignty to one side".[85] The "sovereignty first and foremost" group is defined as that which proposes policies which must have for an end objective the solidification of Canada's total legal control of the Passage. The "sovereignty to one side" group, by contrast, is concerned with the specific challenges associated with the Northwest Passage, including environmental and military security, and not ultimately concerned about the solidification of Canadian sovereignty.[86]

[85] Andrea Charron. "The Northwest Passage: Is Canada's sovereignty floating away?", International Journal, Summer 2005, pp. 833 and 839

[86] Ibid.

What a game-theoretic analysis makes clear, however, is that the government's particular policies must fall within the envelope of a larger strategy (i.e., to invest high or low) given the best response of the United States. Charron's two groups are not mutually exclusive - it is possible to be concerned with the enactment of particular policies, and still have an overarching objective to either solidify or eschew Canada's claim to sovereignty. Since the Northwest Passage is essentially a strategic investment problem, Canada cannot afford to dismiss the issue of sovereignty altogether or it risks a less desirable outcome.

If Canada continues with the US in an "agree to disagree" arrangement over the legal status of the Northwest Passage into the foreseeable future, it must be careful that its actions are consistent with a strategy which either aims to ultimately confirm sovereignty or establish an alternate regime. Although it is difficult to suggest when or how Canada should address the issue (i.e., through direct negotiation or a deepening of bilateral arrangements), as Byers says, the issue of the Northwest Passage ultimately "cannot be avoided".[87]

6 Future Research

Given that the issue of the Northwest Passage continues to unfold, there will be many possibilities for future research. One of the most immediate would be to explore different flavours of the game modelled in Section 5. In particular, the game presented in this paper is simultaneous, and not sequential. Additional modelling with a sequential game may be able to generate further policy recommendations. The game could be further enriched by explicitly incorporating a bargaining process (with asymmetric barganining power) between Canada and the United States which determines the

[87]Michael Byers."Arctic sovereignty: Another threat runs silent and deep",
The Globe and Mail, April 9 2009.
Available at: `http://www.theglobeandmail.com/news/opinions/article974944.ece`

bilateral regime.

A second interesting avenue of research might be related to entry deterrence and arctic investment. The Russian government is heavily pursuing investment in the Northern Sea Route, while the Panana Canal is undergoing expansion. This may be an entry deterrence problem: given the actions of these two other players, Canada may face barriers in attracting international shipping through the Northwest Passage.

7 Conclusion

This paper introduced two related segments of economic analysis in an attempt to decompose the policy issue of the Northwest Passage. In Section 3, the stochastic control model demonstrated that a shipping line's decision to switch their fleet to arctic vessels was positively influenced by the probability of the Northwest Passage opening for navigation in the future, as well as the overall level of profit from operating such vessels relative to their bluewater alternative. Insofar as government investment provides the appropriate infrastructure and scientific research to facilitate shipping in the Northwest Passage, it will help to increase the incentive for shipping lines to switch to arctic vessels. Moreover, shipping in the Northwest Passage will also result in a demand for security, which will also necessitate investment by Canada.

While the possibility of shipping through the Northwest Passage will necessitate investment, Canada must also consider its level of investment in the context of its dispute with the United States over the legal status of the Northwest Passage. The game presented between Canada and the United States in Section 5 stresses that Canada's overall level of investment should be informed by the strategy of the United States; in a world where the United States has the ability to challenge Canada successfully over the legal status of the Northwest Passage, Canada must carefully consider US strategic interests. Furthermore, both the policy literature and the current signals

from the United States suggest that Canada may have the opportunity to reach a Nash Equilibrium where it obtains sovereignty through a high level of investment. Ultimately, Canada will need to determine what sovereignty is worth, and whether it is desirable (and feasible) to invest for sovereignty over the Northwest Passage. These considerations cannot be ignored.

The future of the Northwest Passage remains uncertain. A responsible Canadian policy, however, must recognize and prepare for the likelihood that the region may face increased activity in the future. Moving forward, as Canadian policy continues to develop, the economic implications of the issues discussed herein will become increasingly relevant to Canadians. In order to be prepared, Canada must not only thoroughly analyze the costs and benefits of its own actions, but it must also monitor whether its own actions are consistent with the strategic priorities of the United States.

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A Appendix A

Model Assumptions:

$$\begin{aligned} \pi_{NA} &> \pi_{PA} && \text{(A.1)} \\ \pi_{PB} &> \pi_{PA} && \text{(A.2)} \\ \pi_{NA} &> \pi_{PB} && \text{(A.3)} \\ \pi_{PB} &> 0 \geq \pi_{NB} && \text{(A.4)} \end{aligned}$$

Second Ship Choice:
Second ship choice, if A was chosen as the first ship:

$$\begin{aligned} E(A_2|A_1) &= p(2\pi_{NA} + s) + (1-p)(2\pi_{PA} + s) \\ &= p(2\pi_{NA}) + (1-p)(2\pi_{PA}) + s \\ E(B_2|A_1) &= p(\pi_{NA} + \pi_{PB}) + (1-p)(\pi_{PA} + \pi_{PB}) \\ &= p\pi_{NA} + (1-p)\pi_{PA} + \pi_{PB} \\ E(A_2|A_1) - E(B_2|A_1) &= p\pi_{NA} + (1-p)\pi_{PA} + s - \pi_{PB} \qquad \text{(A.5)} \end{aligned}$$

Second ship choice, if B was chosen as the first ship:

$$\begin{aligned} E(A_2|B_1) &= p(\pi_{PB} + \pi_{NA} + s) + (1-p)(\pi_{PB} + \pi_{PA} + s) \\ &= p\pi_{NA} + (1-p)\pi_{PA} + \pi_{PB} + s \\ E(B_2|B_1) &= p(2\pi_{PB}) + (1-p)(2\pi_{PB}) \\ &= 2\pi_{PB} \\ E(A_2|B_1) - E(B_2|B_1) &= p\pi_{NA} + (1-p)\pi_{PA} + s - \pi_{PB} \qquad \text{(A.6)} \end{aligned}$$

N.B. that (A.5) and (A.6) are the same condition, because the model follows a Markov process. Setting $\pi_{PA} = 0$ produces the condition (3.9) in Section 3:

$$E(A_2) - E(B_2) = p\pi_{NA} + s - \pi_{PB} \qquad \text{(A.7)}$$

First Ship Choice:
First ship choice, if A will be chosen as the second ship:

$$\begin{aligned} E(A_1 + A_2|A_2) &= p\left(\pi_{NA} + \delta(2\pi_{NA} + s)\right) + \\ &\quad (1-p)\left(\pi_{PA} + \delta\left[2p\pi_{NA} + (1-p)(2\pi_{PA} + s)\right]\right) \qquad \text{(A.8)} \\ E(B_1 + A_2|A_2) &= (1-p)\left(\pi_{PB} + \delta\left[p(\pi_{PB} + \pi_{NA} + s) + (1-p)(\pi_{PB} + \pi_{PA} + s)\right]\right) \\ &\quad + p\left(\pi_{PB} + \delta(\pi_{PB} + \pi_{NA} + s)\right) \qquad \text{(A.9)} \end{aligned}$$

Setting $\pi_{PA} = 0$ and subtracting (A.9) from (A.8) we obtain the following:

$$\begin{aligned} E(A_1 + A_2|A_2) - E(B_1 + A_2|A_2) &= p\left[1 + 2\delta(2-p)\right]\pi_{NA} - (1+\delta)\pi_{PB} - p\delta(2-p)\pi_{NA} \\ &= p\pi_{NA} + p\delta(2-p)\pi_{NA} - (1+\delta)\pi_{PB} \end{aligned} \tag{A.10}$$

We may incorporate (A.7) to rewrite (A.10) in a form identical to (3.13) from Section 3:

$$E(A_1 + A_2|A_2) - E(B_1 + A_2|A_2) = [p\pi_{NA} - \pi_{PB} + s] - [s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] \tag{A.11}$$

Since A was chosen as the second ship in this case, $p\pi_{NA} + s - \pi_{PB} > 0$; the left bracketed term of (A.11) is positive.

From (A.11), in order for A to be chosen as the first ship:

$$[s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] < [p\pi_{NA} - \pi_{PB} + s]$$

And a B ship is instead chosen if:

$$[s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] > [p\pi_{NA} - \pi_{PB} + s]$$

First ship choice, if B will be chosen as the second ship:

$$\begin{aligned} E(A_1 + B_2|B_2) &= (1-p)\left[\pi_{PA} + \delta\left[p\pi_{NA} + (1-p)\pi_{PA} + \pi_{PB}\right]\right] + \\ &\quad p\left[\pi_{NA} + \delta(2\pi_{NA} + s)\right] \end{aligned} \tag{A.12}$$

$$E(B_1 + B_2|B_2) = (1-p)\left[\pi_{PB} + \delta\left[2\pi_{PB}\right]\right] + p\left[\pi_{PB} + \delta(\pi_{PB} + \pi_{NA} + s)\right] \tag{A.13}$$

Setting $\pi_{PA} = 0$ and subtracting (A.12) from (A.13) we obtain the following:

$$\begin{aligned} E(A_1 + B_2|B_2) - E(B_1 + B_2|B_2) &= \left[(1-p)\delta - \left[1 + \delta(2-p)\right]\right]\pi_{PB} + \\ &\quad \left[p\left[1 + \delta(3-p)\right] - p\delta\right]\pi_{NA} \\ &= p\left[1 + \delta(2-p)\right]\pi_{NA} - (1+\delta)\pi_{PB} \end{aligned} \tag{A.14}$$

We may incorporate (A.7) to rewrite (A.14) in a form identical to (3.13) from Section 3:

$$E(A_1 + A_2|A_2) - E(B_1 + A_2|A_2) = [p\pi_{NA} - \pi_{PB} + s] - [\delta + \delta\pi_{PB} - p\delta(22-p)\pi_{NA}] \tag{A.15}$$

Since B was chosen as the second ship in this case, $p\pi_{NA} + s - \pi_{PB} < 0$; the left bracketed term of (A.15) is negative.

From (A.15), in order for A to be chosen as the first ship:

$$[s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] < [p\pi_{NA} - \pi_{PB} + s]$$

And a B ship is instead chosen if:

$$[s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] > [p\pi_{NA} - \pi_{PB} + s]$$

Ship Choice - Ruling out B_1, A_2

It can easily be shown that the shipping line would not choose B_1, A_2 provided that $p\pi_{NA}$ is greater than π_{PB}. In order for a shipping line to select B_1, A_2 the following conditions must hold:

$$\begin{aligned} [p\pi_{NA} - \pi_{PB} + s] &> 0 \\ \text{p}\pi_{NA} - \pi_{PB} + s - [s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA}] &< 0 \end{aligned}$$

Which in turn implies that, in the second expression,

$$\begin{aligned} p\pi_{NA} - \pi_{PB} + s &< s + \delta\pi_{PB} - p\delta(2-p)\pi_{NA} \\ p\pi_{NA} - \pi_{PB} &< \delta(\pi_{PB} - 2p\pi_{NA} - p^2\pi_{NA}) \end{aligned}$$

However, if $p\pi_{NA} > \pi_{PS}$, it must be true that:

$$p\pi_{NA} - \pi_{PB} > \delta(\pi_{PB} - 2p\pi_{NA} - p^2\pi_{NA})$$

Therefore, a shipping line will never select B_1, A_2.

B Appendix B

Strategies

United States :	*Canada* :
S="Canada Sovereign"	H="High Investment"
N="International Straight"	L="Low Investment"

United States
If Canada plays H, US plays S if:

$$B - D \geq 0$$

Substituting for B and D we have,

$$\begin{aligned} p(2(S-L) - \alpha(1-\theta)) + I_{US} &\geq 0 \rightarrow \text{US plays S} \\ p(2(S-L) - \alpha(1-\theta)) + I_{US} &\leq 0 \rightarrow \text{US plays N} \end{aligned}$$

Rearranging for α we have

$$\frac{2p(S-L) + I_{US}}{p(1-\theta)} \geq \alpha \rightarrow \text{US plays S}$$

If Canada plays L, US plays S if:

$$F - H \geq 0$$

Substituting for F and H we have,

$$\begin{aligned} p(2(S-L) - \alpha\theta) + I_{US} &\geq 0 \rightarrow \text{US plays S} \\ p(2(S-L) - \alpha\theta) + I_{US} &\leq 0 \rightarrow \text{US plays N} \end{aligned}$$

Rearranging for α we have:

$$\frac{2p(S-L) + I_{US}}{p\theta} \geq 0 \rightarrow \text{US plays S}$$

Alpha Conditions (Lemma 1)
Since $\theta > (1-\theta)$ by assumption we have $\frac{2p(S-L)+I_{US}}{p(1-\theta)} > \frac{2p(S-L)+I_{US}}{p\theta}$

Therefore,

$$\begin{aligned} \frac{2p(S-L) + I_{US}}{p\theta} \geq \alpha &\rightarrow \text{S is a dominant strategy} \\ \frac{2p(S-L) + I_{US}}{p(1-\theta)} \leq \alpha &\rightarrow \text{N is a dominant strategy} \\ \frac{2p(S-L) + I_{US}}{p(1-\theta)} > \alpha > \frac{2p(S-L) + I_{US}}{p\theta} &\rightarrow \text{US strategy is contingent on Canada's} \end{aligned}$$

Canada

If US plays S, Canada plays H if:

$$A \geq E$$

Substituting for A and E we have,

$$\begin{aligned} p(\psi - \gamma) + I_{CAN,L} - I_{CAN,H} &\geq 0 \rightarrow \text{Canada plays H} \\ p(\psi - \gamma) + I_{CAN,L} - I_{CAN,H} &\leq 0 \rightarrow \text{Canada plays L} \end{aligned}$$

Rearranging for $(I_{CAN,H} - I_{CAN,L})$:

$$p(\psi - \gamma) \geq (I_{CAN,H} - I_{CAN,L}) \rightarrow \text{Canada plays H}$$

If US plays N, Canada plays H if:

$$C - G \geq 0$$

Substituting for C and G we have,

$$\begin{aligned} p\alpha(2\theta - 1) - I_{CAN,H} + I_{CAN,L} &\geq 0 \rightarrow \text{Canada plays H} \\ p\alpha(2\theta - 1) - I_{CAN,H} + I_{CAN,L} &\leq 0 \rightarrow \text{Canada plays L} \end{aligned}$$

Rearranging for $(I_{CAN,H} - I_{CAN,L})$:

$$p\alpha(2\theta - 1) \geq (I_{CAN,H} - I_{CAN,L}) \rightarrow \text{Canada plays H}$$

Investment Conditions (Lemma 2)

Since $(\psi - \gamma) > \alpha(2\theta - 1)$ by assumption we have:

$$\begin{aligned} p\alpha(2\theta - 1) \geq (I_{CAN,H} - I_{CAN,L}) &\rightarrow \text{H is dominant strategy} \\ p(\psi - \gamma) \leq (I_{CAN,H} - I_{CAN,L}) &\rightarrow \text{L is dominant strategy} \\ p(\psi - \gamma) > (I_{CAN,H} - I_{CAN,L}) > p\alpha(2\theta - 1) &\rightarrow \text{Canada's strategy is contingent on U.S.} \end{aligned}$$