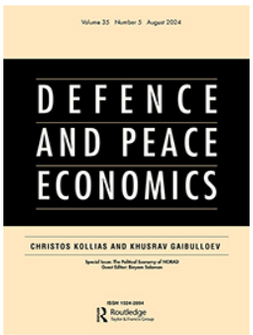

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Canada and the NORAD: Economics and Burden Sharing

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ABSTRACT

We quantify the burden sharing between the United States and Canada within the context of the bi-lateral defense relationship regarding the North American Aerospace. Also known as the North American Aerospace Defense Command (NORAD), this bi-lateral military alliance has existed since the late 1950s. We use insights from the economic theory of military alliances as well as disaggregated defense expenditures on capital, labor and R&D to tease out nuanced assessment of burden sharing between the two countries and peer groups (Arctic Council). In addition, we provide some funding scenarios for the planned policy review in Canada to guide decision makers. We also show that there are considerable strategic, institutional, and operational constraints facing the fulfilment of Strong, Secure, Engaged (Defence Policy) and possible NORAD modernization. Improving these institutional issues, along with fulfilling the commitments outlined in the Defence Policy, will go a long way to assuaging the burden sharing debate.

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JEL CLASSIFICATION
D74; H42; H56

Introduction

Early in the morning of 24 February 2022, the Russian Federation launched an invasion of Ukraine and likely marking it Europe's largest since the Second World War (Economist, 2022). The invasion is a major escalation of the ongoing Russo-Ukrainian War since the annexation of Crimea in March 2014. After years of complacency and security under investment, the Russian invasion has spurred European Union (EU) member states to announce increases in their defense budgets close to an additional €200 billion in the coming years.[1]

Similarly, in the North American theatre, Canada and the United States (U.S.) have traditionally relied on the relative protection of geography, surrounded by the Arctic, Atlantic and Pacific oceans. However, in addition to the invasion in Europe, the geographic advantage is being challenged by the development of hypersonic weapons, as well as counter-space weapons. The possibility of Russia, China or North Korea using more nuclear weapons against the continent implies a renewed focus and re-examination of the capabilities of the North American Aerospace Defense Command (NORAD). NORAD is bi-national (U.S.-Canada) military agreement that provides aerospace warning, air sovereignty, and protection.

Canada also promised to review its 5-year-old defense policy considering the changing security environment and about $8B (CAD) in new funding over the next 5 years (Canada, 2022). The

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possibility of raising Canada's defense budget to 2% of GDP (in accordance with NATO's guidelines) is also mentioned[2] although no serious commitment or announcements have been made.

In this paper, we examine NORAD burden sharing considering the increasing threat to the North American theatre due to emerging new technologies, a revanchist Russia, an assertive China, and a rogue nuclear capable North Korean state. Russia as an Arctic state and China as a self-declared near Arctic state have increased their presence and interest in the polar region due to the region's potential natural resources and strategic position for international travel and trade. The burden sharing assessment is also motivated by the fact that the North Warning System, the backbone of the bi-national early-warning radar system, is due for an upgrade (it is based on technology from the 1980s). Finally, there is no official or empirical literature that quantifies the cost or burden sharing of this unique bi-lateral military arrangement.

Using measures common in the literature, our analysis shows that the US shoulders a disproportionate amount of the bi-lateral defense burden. Assessing the dynamics, we also show that Canada's net benefit (benefits minus burden) has increased during the Post-Cold War era. We also assess the benefit-burden concordance with peer states in the Arctic given the strategic importance of the region. Within the peer group, Canada contributes roughly 47% of the defense spending. However, it also receives 64% of the benefit. However, a disaggregated view of military burden by key inputs shows a more balanced burden sharing among the two countries. We also examine some policy implications of the burden sharing with emphasis on funding and institutional capacities.

The rest of the paper contains four sections. Section 2 provides a brief review of the economics of alliances followed in Section 3 by a description of the methodology, data, and sources. Section 4 presents the results including the burden benefit concordance within the Arctic Council peer groups. The last section concludes and provides directions for future research.

Brief Review of the Literature

There is limited literature on the economic assessment of the NORAD military alliance. We do note the strategic and political science literature on NORAD. For example, the political choice perspectives and strategic implications of the bilateral alliance are effectively discussed in Charron and Fergusson (2020), Fergusson (2010) Jockel and Sokolsky (2015). Since our study is primarily economic, we begin the literature review by summarizing the economic theory of military alliances (Sandler and Hartley 2001). According to the theory, nations form bi-lateral or multi-lateral defense arrangements if the arrangement provides benefits that exceed the cost of joining. Sometimes joining an alliance is almost costless if one ally can provide deterrence that guarantees protection to all regardless of the size of the alliance. For example, the U.S. nuclear umbrella during NATO's doctrine of Mutual Assured Destruction (MAD) protected additional allies without diminishing the protection available to existing allies. Furthermore, once nuclear deterrence is provided it is available to all allies. In such a costless scenario, the dominant ally capability is 'exploited' by the smaller allies (see also Olson and Zeckhauser 1966).

It should be emphasized that the relaxation of any of the assumptions that underpin the Public Goods Model (exploitation hypothesis) has significant implications to burden sharing within an alliance (Sandler and Hartley 2001). For example, the Joint Products Model, where defense may produce multiple products with varying degrees of publicness (Sandler and Hartley 2001), is the relaxation of the assumption that incentive to contribute to an alliance is weak and the match between benefits received from defense and costs (burden) is smaller. Consider, for example, NATO's flexible response doctrine of the late 1960s.

Flexible response doctrine required nations to rely on a full spectrum of forces, both conventional and strategic (nuclear pure public good). Since conventional forces need to be deployed both in support of the alliance and own borders (partially rival and excludable), nations needed to invest in

self-protection. Some of these conventional forces provided other country-specific benefits such as national search and rescue and aid to civil authority capabilities. Thus, the more country-specific benefits of defense spending that accrue to a nation, the more likely it will fund such spending, and exploitation (free-riding by the smaller nation) is less prevalent (Sandler and Hartley 2001).

To empirically validate the theoretical framework described above, the economics literature initially utilized an ability to pay measure as a gauge for disproportionality (Olson and Zeckhauser 1966). This disproportionality of defense burdens is typically tested non-parametrically by checking the rank correlation between the allies' defense burdens and their GDP. Since larger countries tend to shoulder the largest burden in a pure public good setting, another key assumption, a significant relationship between GDP and burden is a signal of exploitation of the large by the small members. The exploitation hypothesis had a short empirical shelf-life as all empirical tests failed to find positive association between GDP and burden after the MAD era.

Given the MAD doctrine's heavy emphasis on deterrence, a pure public good, these results are consistent with the theoretical predictions. By 1967, NATO's doctrine changed to flexible response, a strategy of measured response to the Warsaw Pact aggression. Specifically, if the Warsaw pact initiated a small conventional force incursion, NATO will respond with similar conventional countermeasures (Kim and Sandler 2020).

The doctrine effectively made allies' defense efforts complementary to one another (Murdoch and Sandler 1984) as predicted by the joint product model. To empirically validate the joint product model and to understand the state of burden sharing in NATO post 1967, empirical models utilized measures of defense burdens and benefits. Sandler and Forbes (1980) utilized an 'among-ally burden'[3]by relating an ally's share of NATO's total spending to its derived benefits from being defended.

Sandler and Forbes (1980) define among-ally benefit as a simple average of GDP, population, and exposed border. Specifically, a nation's military expenditures protect the industrial base (GDP), people (population) and territory (exposed borders). A simple average of the benefits has generated some debate. As Khanna and Sandler (1996) acknowledged, 'a myriad weighting schemes conceivably could be employed' but the lack of knowledge of the ally's utility function (regarding the three benefit proxies) constrains one to use a simple average (Khanna and Sandler 1996, 125).

Apart from the search for the 'optimal' weights for the benefit measures, a constant concern for member states of NATO is the appropriateness of any burden or benefit measures. Rowlands (2015), for example, notes Canada's extensive coastline makes it the largest free rider in the alliance. Solomon (2004, 2005) and Sandler (2005) debate the weighting scheme and the implication of adding or removing the exposed border proxy. On the measurement of burdens, Hanson (2016) and Beeres and Bollen (2017) suggest disaggregating defense expenditures to better reflect the production of military capabilities.

The various extension of both the benefit and burden measures as outlined above generally support the joint product model's prediction that burdens, and benefits are more aligned after the flexible response era (Sandler and Hartley 2001). The results also held up into the 1990s (except in 1985 with the Regan build-up) and 2000s (Sandler and Shimizu 2014). However, with the shift in NATO's doctrine to crisis response in the late 1990s, some weaker evidence of the exploitation hypothesis began to emerge (Sandler and Shimizu 2014).

Hartley (2020) and Kim and Sandler (2020) outline some of the key changes in NATO doctrine, missions and threats that explain the changing burden sharing calculus. First, the out of area missions provide purely public benefits to allies in the form of global stability, increased foreign direct investment opportunities and trade. Second, Russia has emerged as a territorial threat reflected in the annexation of Crimea (February–March 2014) and the invasion of east Ukraine.

Another key assumption from the exploitation hypothesis is the additive and perfect substitutability between individual contributions and the overall level of the public good that leads to suboptimal provision of the public good. Hirshleifer (1983) provides one possible aggregation technology, 'weakest link' within the context of identical tastes and income.

Specifically, the smallest contribution level determines the overall provision (weakest link) since everyone desires the same level of provision and will match one another's contributions to the collective good. The examination of the theoretical bounds of relaxing various aggregation technologies and game forms, other than non-cooperative games in the exploitation hypothesis, is a worthwhile extension that we relegate as possible avenue for future research.

While there is no explicit assessment of bilateral relationships in the economics of alliances, the theoretical and empirical setup discussed above provide the framework for examining NORAD burden sharing. Specifically, we adopt the 'among ally' burden concordance to quantify the U.S.-Canada NORAD commitment. Another key assumption that may affect NORAD is that the price of defense is the same in the alliance thus there is no comparative advantage in the production of defense. While a more disaggregated or micro assessment of each country's military production is required to assess any cost advantages, we analyze the relative concordance among burdens and benefits within labour and capital as a first step to assess any potential cost advantages.

Methodology and Data

Due to the unavailability of public NORAD spending figures for both the U.S. and Canada and the fact that the warning and control of North American aerospace and maritime approaches constitutes the fundamental aspect of both countries' defense posture, we begin our analysis by examining the overall military expenditures as the measure of burden. We adopt the relative burden measure (relative share of the US-Canada defense burden) as in Sandler and Forbes (1980). Symbolically,

$$\frac{ME_i}{\sum_i^n ME_i} \tag{1}$$

We also adopt the production function perspective of Hanson (2016) and disaggregate the military expenditure data into capital (procurement and Research and Development, R&D) and labour (military personnel) to further assess the defense burden of the bi-lateral alliance.

A non-parametric assessment requires a reasonably larger sample to derive meaningful statistical inference. As such, for the two-nation NORAD, we analyze the trend and magnitude in the concordance of burden and benefits to demarcate the boundaries of burden sharing in NORAD. Specifically, we analyze the relative burden within NORAD expressed in terms of military expenditures and its subcomponents: procurement, personnel, and R&D (see equation 1).

As noted earlier, the benefit measure is an average of the relative share of GDP, population, and exposed borders. Specifically:

$$B_i = \frac{1}{3}\left(\frac{GDP_i}{\sum_i^n GDP_i} + \frac{Pop_i}{\sum_i^n Pop_i} + \frac{br_i}{\sum_i^n br_i}\right) \tag{2}$$

Where B denotes a relative benefit measure for country *i* within an alliance as the average of the relative share of *GDP*, population (*Pop*) and exposed borders (*br*). The inclusion of the exposed border variable is important in the NORAD perspective even if it penalizes Canada due to its large coastline (Solomon 2004, 2005).[4] The 2006 NORAD agreement includes the maritime approaches of North America and constitutes the largest coastline of any nation.

To provide another perspective on the burden sharing calculus of NORAD, the study situates Canada within the Arctic Council countries. Specifically, the study observes the burden-benefit concordance between Canada, Denmark, Finland, Norway, and Sweden. The purpose of this exercise is to illustrate potential future geo-strategic alignment given the importance of the polar region for resource extraction and international travel. In addition, if Canada is serious about its northern region both for the protection of its indigenous populace and economic survival, then a comparison to some of its competitors/allies is warranted.

We also provide a first estimate of the likely additional spending required to make Canada as a reliable ally while acknowledging the potential marginal cost differential that may confer some advantages to Canada. Specifically, we assess the incremental cost of expediting and implementing the 2017 defense policy as the minimum required for burden sharing followed by various force structure scenarios and potential increase of spending to equal 2% at the high end of the spectrum.

Data

We utilize the standard datasets as in the extant literature such as military expenditures and defense burden (military expenditure as a share of GDP) from Stockholm International Peace Research Institute (Stockholm International Peace Research Institute- SIPRI 2021) for the period 1972 to 2020. GDP, population, and price indices from the World Economic Indicators (World Bank 2020) and exposed borders, proxied by coastlines and land borders with non-NATO countries from the World Fact Book (Central Intelligence Agency-CIA 2021). To facilitate international comparisons, we employ a standard definition of R&D. Specifically, we adopt the Frascati definitions, which are developed by the Organization for Economic Development and Cooperation (OECD). The OECD database is updated biannually, and the most recent update (2022) includes preliminary estimates for the years 2019 and 2020.[5] The most recent data for Canada are 2018 thus we use data from Statistics Canada (2022) to impute missing values. Particularly, we use 'Federal expenditures on science and technology, by major departments and agencies.' We convert GDP and military expenditures (ME) data into constant 2020 U.S. dollars using the GDP deflator of each member country.

Results

We begin the analysis by examining the burden sharing in NORAD using the burden-benefit concordance. As noted earlier, relative burdens are the share of each of Canada and the U.S. military expenditures to the combined total. Similarly, the relative benefit measures are the average share of income (GDP), population and exposed borders.

Table 1. Burden-benefit concordance U.S. and Canada.

	Relative Burden		Avg. Share	
Year	Canada	U.S.	Canada	U.S.
1972	2.02	97.98	35.59	64.41
1980	2.77	97.23	35.89	64.11
1985	2.46	97.54	35.79	64.21
1990	2.63	97.37	35.79	64.21
1995	2.84	97.16	35.66	64.34
2000	2.67	97.33	35.62	64.38
2005	2.08	97.92	35.70	64.30
2010	1.95	98.05	35.77	64.23
2011	2.04	97.96	35.84	64.16
2012	2.06	97.94	35.83	64.17
2013	2.06	97.94	35.85	64.15
2014	2.22	97.78	35.86	64.14
2015	2.61	97.39	35.75	64.25
2016	2.65	97.35	35.74	64.26
2017	3.21	96.79	35.79	64.21
2018	3.11	96.89	35.82	64.18
2019	2.91	97.09	35.84	64.16
2020	2.90	97.10	35.77	64.23
Average	**2.50**	**97.50**		
Average (less Borders)			**8.75**	**91.25**

The Average is for the entire sample period (1972–2020).

Given the relative size of the U.S. and Canada both militarily and economically, the bi-lateral defense alliance is asymmetric. For example, using constant U.S. dollars, the U.S. spent about $778B compared to Canada's military spending of $23B in 2020. Economically, the U.S. is roughly 13 times bigger. Thus, the relative burden-benefit concordance in NORAD's context tends to favor Canada. For example, Table 1 depicts the relative burden and benefits for selected years. The U.S. shoulders about 97.6% of the North American defense burden but receives about 64% of the benefits. Meanwhile, Canada contributes about 2% of the burden and enjoys 36% of the benefits. Acknowledging the vast Canadian coastline and for completeness, we remove the exposed border variable and assess the burden-benefit concordance. While the U.S. now enjoys 91% of the benefits for 97.6% of the cost, Canada now receives only 9% of the benefits. However, Canada's burden-benefit ratio is still 1:3.5. While excluding the border gives the U.S. an almost equal burden-benefit ratio, the new geostrategic reality requires less pre-emptive engagement out of area and a more nuanced protection of the homeland. This North American focus implies more surveillance and control of all domains of the continent. As such, the disproportionate concordance may become an irritant to the long-standing Canada-U.S. defense relationship.

As pointed out earlier, there are no publicly available data on NORAD specific activities by the U.S. and Canada. However, as shown in Figure 1, a sizable portion of the warning and control systems are deployed in the Canadian territory. The map identifies both the Canadian air defense zones, as well as the division between east and west boundaries. The Air Defense Identification Zone (ADIZ) of North America covers the airspace surrounding both countries to provide the space for the identification, location, and control of civil aircraft over the territory. Assuming the production function of the aerospace defense of the North American theatre requires both land and radar systems, we can compare burdens using these production inputs.[6]

While warning and control systems are deployed in both the U.S. and Canada, the cost sharing does not seem to follow any fairness or operational criteria. Jockel (2007) points out the original

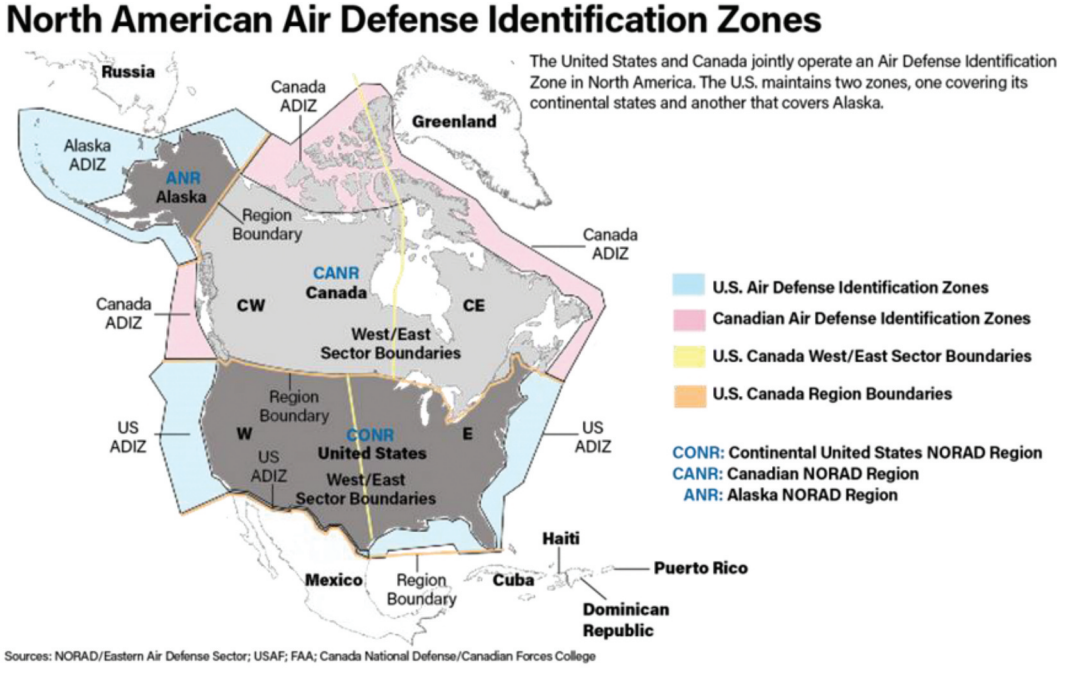


Figure 1. [???]NORAD air defence identification zones Sherman (2021). https://www.airforcemag.com/article/forging-a-shield-for-the-homeland.

Table 2. Burden-benefit concordance land/systems.

	Canada		U.S.		Average Burden		Avg. Benefit Share		Net Benefit	
	Land	Systems	Land	Systems	Canada	U.S.	Canada	U.S.	Canada	U.S.
DEW	0.718	0.00	0.28	1.00	0.36	0.64	0.36	0.64	0.001	−0.001
NWS	0.867	0.40	0.13	0.60	0.63	0.37	0.36	0.64	0.276	−0.276
MilEX_DEW Era	0.024		0.98		0.25	0.75			−0.111	0.111
MILEX-NWS Era	0.025		0.98		0.43	0.57			0.073	−0.073

Distant Early Warning Line (DEW Line) operated from 1957 to 1993 and was entirely funded by the U.S. The replacement known as the NWS, operational since 1993, is funded on a 60/40 U.S./Canada cost sharing.[7] Interestingly, Canada housed about 73% of the long-range radars and 92% of the short-range radars. Similarly, the expanded NORAD role established in 2006 is looking for the modernization of the NWS to address emerging threats from Russia, North Korea and possibly China. The cost sharing formula is not established, but the 60/40 split is anticipated to continue.

Using the above information we construct a burden-benefit concordance for the two key periods of NORAD. The first period deals with the construction and deployment of the Distant Early Warning (DEW) systems from 1972 to 1984 and the North warning System (NWS) from 1985 to 2019.[8] For the land input, we use the proportion of land area used by each nation while for the system input, we use the cost share for the construction and deployment of the radar systems. Specifically, 100% and 60% of the costs of the systems are attributed to the U.S. during the DEW and NWS periods, respectively.[9] The benefit measures are calculated as before (equation 2).

Table 2 presents the average (for the period) benefit and burden shares for the U.S. and Canada. We also include the total military expenditures for the period as an additional burden measure. During the DEW period and using the two inputs as a measure of burden, Canada shouldered 36% of the burden and similar amount in benefits. Similarly, the U.S. experienced balanced burden-benefit concordance during the DEW period. However, with the cost of systems split 60/40 in favor of the U.S., Canada's burden jumps to 27% after accounting for benefits. During the NWS period, Canada shoulders more of the burden (net of benefit) even when including total military expenditures in the burden share measure. Including Canada's land area as a burden measure in the production of warning and control of aerospace, provides a nuanced view of the NORAD burden sharing argument.

We reiterate that in the absence of NORAD specific spending data for both the U.S. and Canada, the production function approach is possibly at one end of a burden sharing outcome. First, following the traditional empirical literature, we valued both inputs (land and radar systems) equally. This assumption may be too strong if some nations value land less (especially in a sparsely populated and harsh environment) versus land in a cosmopolitan and dynamic area. Land can also generate private benefits if it contains resources or economic activities because of the stationing of the warning systems. These aspects are discussed in Berkok et al. (this issue) and Stone (this issue).

Second, the warning and control capability of the NWS implicitly relies on signal interpretation as well as interception and air superiority capabilities of both nations. In the absence of detailed information on NORAD assets and force structure, the production function approach provides only partial picture. Finally, the recent expansion of the NORAD mandate to include maritime approaches requires the inclusion of Naval assets to the mix. In order to address these issues, we next examine the major sub-components of military inputs.

Relative Burdens: Military Expenditures and Components

Before analyzing the various inputs of military expenditures, we note a recent study on Canadian demand for military expenditures that highlighted the post-Cold-War weaker defense posture

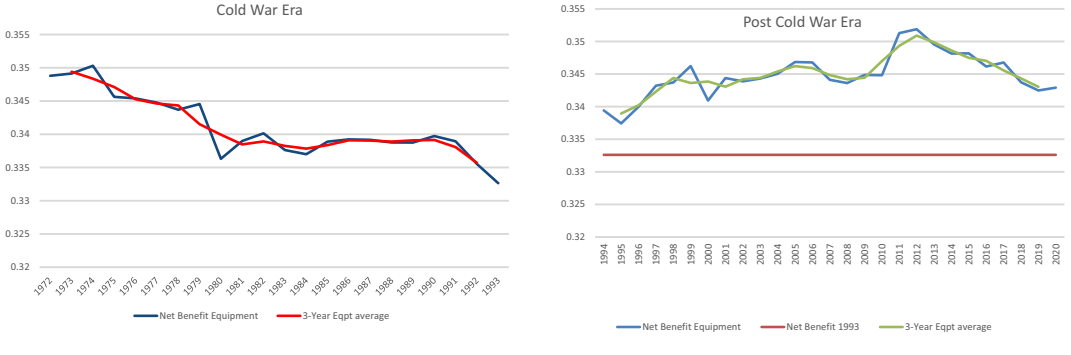
Panel A Panel B

Figure 2. Canadian net benefit based on military expenditures based on absolute values of the net benefit (benefits minus burdens).

(Skogstad and Compton 2022). In subsequent analyses, we also examine military spending dynamics to ascertain whether there is some movement towards improving (worsening) burden sharing within NORAD. Specifically, we compute a net benefit measure (benefits minus burden) and plot the trajectory[10] The disaggregated view of military inputs on a yearly basis may hide the fact that R&D or equipment spending has cumulative effects. Middleton et al. (2006) point out that current equipment embeds R&D from about 15–20 years ago. To reflect this possibility, we also use a 3-year moving average in the calculation of burden-benefit concordance.[11]

Figure 2 panel A presents the net benefit trend for Canada during the Cold War (1972–1993) the start date is constrained by available comparable data while the end date of 1993 coincides with Canada's complete withdrawal from European theatre. Net benefits peaked at 33.6% in 1982 and steadily declined to 32.9% by 1993. This lower level implies that Canada's NORAD benefit-burden concordance ameliorated. In panel B, we show the post-Cold War period trend. We indicate the lower net benefit level achieved in 1993 in red to compare the post-Cold war performance. Note that from 2002 to 2016, Canada's net benefit exceeded the lowest achieved during the Cold War. In some periods, it also exceeded the highest achieved during the Cold War.

This indicates that Canada enjoyed the benefits of the peace dividend relative to the U.S. The use of a moving average (3-year) for the aggregate military expenditure variable demonstrates the impact of past expenditures on the burden-benefit concordance. Note, for example, the impact of increased military spending during the flexible response era and the accumulated effect it had even during the Regan build-up. The net benefit measure decline is more pronounced using the 3-year average.



Panel A Panel B

Figure 3. Canadian net benefit equipment based on absolute values of the net benefit (benefits minus burdens).

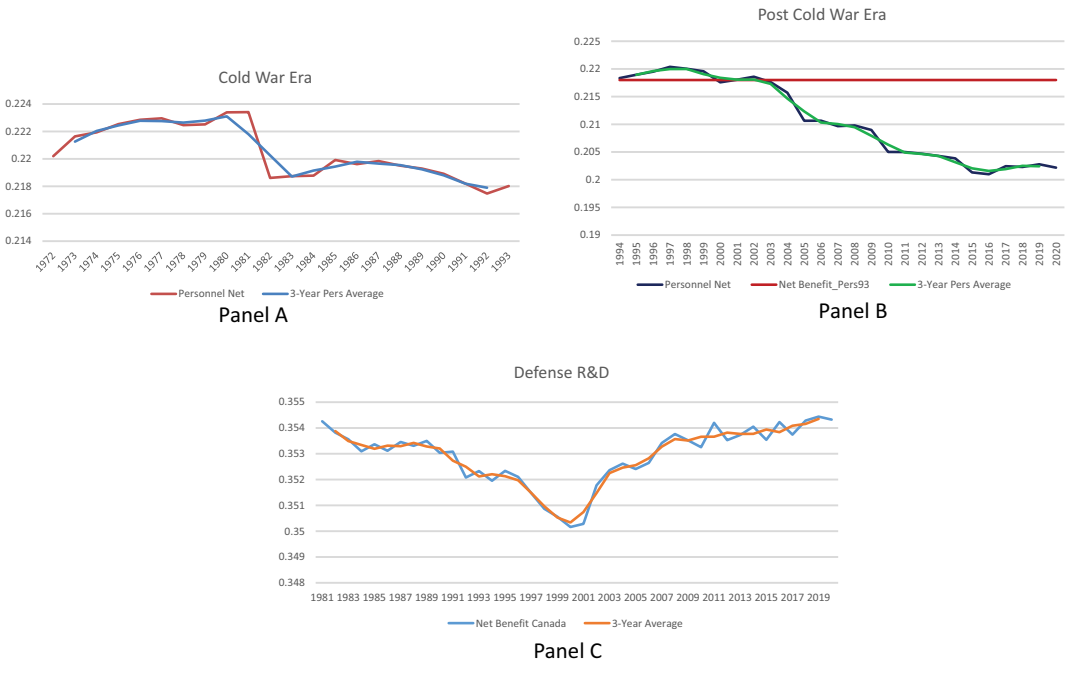


Figure 4. Canadian net benefit based on personnel numbers and R&D spending based on absolute values of the net benefit (benefits minus burdens).

Next, we disaggregate total military expenditures into personnel (labor), equipment (capital) and research and development (R&D). Figure 3 panel A displays Canadian net benefit in equipment share during the Cold War era. Canada enjoys higher benefits, and this advantage persists and worsens during the post-Cold War era as well (Panel B). We observe a *relatively* balanced burden sharing between the two nations when using personnel as the input measure (Figure 4). This balanced burden sharing profile is more pronounced in the post-Cold War era (Figure 4 panel B). One possible interpretation is that Canada has a relative cost advantage in personnel or the Army as a labor-intensive service is better positioned to share the burden. It should be noted that the Canadian Army is disproportionately utilized in Afghanistan and most non-UN mission during the post-Cold War era (Solomon 2019).

Figure 4 panel C highlights the burden-benefit concordance related to R&D. Here, we do see excessive free-riding where Canada's share of the bi-lateral R&D output less than one-half of 1%. While we do not have sufficient time-series data to assess the pre- and post-Cold War periods as the other sub-components of military expenditures, we do note that the concordance improved steadily from 1981 to 2001 before reversing the trend post 2001. The R&D results are not surprising since the U.S. has been the global leader in defense R&D especially among allies. While we use a 3-year moving average measure in all the input variables considered (Figure 3), it shows only marginal effect on the burden-benefit concordance. However, this is due to the highly asymmetric power differential between Canada and the U.S. In a dynamic multi-lateral examination of burden-benefit concordance such as the EU or NATO, the measure promises a more balanced perspective.

Arctic Security

We now direct our focus to the Arctic region, which is not only part of the NORAD air defense area but also an emerging strategic region both economically and militarily. The establishment of the Arctic Council (in 1996), while originally an environmental monitoring and protection forum of the

Table 3. Burden-benefit concordance select Arctic nations.

	Canada		Denmark		Finland		Norway		Sweden	
Year	Burden	Benefit	Burden	Benefit	Burden	Benefit	Burden	Benefit	Burden	Benefit
2000	39.67	62.61	13.61	8.54	6.21	5.88	18.14	11.40	22.37	11.56
2001	40.54	62.66	14.29	8.50	5.83	5.89	18.33	11.42	21.02	11.53
2002	39.47	62.88	13.50	8.40	5.71	5.86	21.66	11.37	19.66	11.49
2003	40.16	63.12	12.98	8.30	7.19	5.83	20.43	11.29	19.26	11.46
2004	41.45	63.17	12.94	8.24	7.59	5.82	19.89	11.29	18.14	11.47
2005	43.89	63.40	12.27	8.17	7.83	5.79	17.57	11.23	18.44	11.41
2006	45.28	63.48	13.08	8.15	7.84	5.78	16.12	11.16	17.67	11.43
2007	48.30	63.81	11.84	7.99	6.97	5.77	15.86	11.08	17.03	11.35
2008	50.63	63.93	12.07	7.94	7.50	5.76	14.81	11.09	15.00	11.28
2009	51.89	64.07	10.91	7.87	7.38	5.64	16.17	11.18	13.65	11.23
2010	48.63	64.10	12.08	7.81	7.63	5.63	16.14	11.08	15.53	11.38
2011	50.17	64.21	11.51	7.75	7.82	5.62	15.62	11.02	14.88	11.40
2012	48.62	64.35	12.09	7.70	8.05	5.55	15.78	11.10	15.46	11.30
2013	46.85	64.50	11.64	7.66	8.43	5.48	16.90	11.09	16.18	11.27
2014	46.95	64.60	10.93	7.62	7.84	5.41	17.69	11.07	16.59	11.29
2015	50.67	64.43	9.96	7.64	7.25	5.38	17.01	11.09	15.11	11.46
2016	50.00	64.35	10.27	7.70	7.06	5.38	17.95	11.07	14.73	11.50
2017	54.29	64.42	9.49	7.68	6.30	5.36	16.60	11.04	13.31	11.50
2018	53.13	64.50	10.65	7.67	6.30	5.33	16.52	11.00	13.40	11.50
2019	50.78	64.57	10.88	7.70	6.72	5.29	17.35	10.97	14.27	11.48
Average	*47.07*	*63.86*	*11.85*	*7.95*	*7.17*	*5.62*	*17.33*	*11.15*	*16.59*	*11.42*
*Average**		*54.37*		*10.43*		*7.80*		*11.05*		*16.35*

*Excluding exposed borders.

Arctic region, now also serves to gain recognition of the Arctic States' sovereignty, sovereign rights, and jurisdiction in the Arctic. While the Arctic Council is not a military alliance, positioning the defense posture of Canada alongside peer Nordic nations provides an alternative comparator and a potential benchmark.

We apply the same relative measure of benefits and burdens and present the results for the period after the creation of the council (2000–2019) in Table 3. This Canadian focus, while consistent with the theme of the article, limits the important security implications for the Nordic nations that are uncomfortably close to the Russian threat than Canada. The empirical assessment of burden sharing in the Arctic needs to be more precise on the choice of variables such as exposed borders. The Canada focus of the article thus limits the analysis to the traditional measures to highlight only how Canada compares to these Arctic smaller powers.[12]

Compared to the selected Arctic states, Canada is indeed larger and contributes roughly 47% of the defense spending. However, it also receives 64% of the benefit. It is also the only country that generates more benefits for a dollar in defense spending. The calculus changes a bit when we remove the exposed border proxy. Here, the benefit-burden concordance is lower for Canada, which receives 54% for its 47% contribution. Finland receives an equal concordance in this scenario.

Alternate Measures

The preceding is to our knowledge the first attempt at quantifying the burden sharing status between the U.S. and Canada. As noted in the survey articles by Hartley (2020) and Rowlands (2015), some nations may have comparative advantage in producing military capabilities which may lead to lower defense budget compared to others that are less efficient. Similarly, the burden measures are input based which do not reveal anything useful about a nation's true capabilities. However, we observe a consistent story about the disproportionate burden sharing between the

U.S. and Canada despite utilizing different combinations of the available measures and peer comparators.

Another useful measure to consider within the context of NORAD is the total cost of upgrading the North Warning System (NWS). However, there are no publicly available information on the requirements and scope of the projects to make a reasonable cost estimate and burden calculus. For example, if the upgrade implies data analytics (and better use of existing data from NWS) the cost could be manageable. Sophisticated shields to counter hypersonic missiles could be on the high end. For these reasons, we opt out from making cost estimates.

We also note that the assessment of the burden sharing calculus does not point to the 'appropriate' level of defense spending for Canada to better reflect the burden-benefit concordance. Even if the preceding assessment of net benefit using military personnel indicated potential Canadian cost advantages, it does not provide a monetary estimate of how much is required to fulfil Canada's bilateral commitment. The 2017 Defense Policy (known as Strong, Secured, Engaged-SSE) promised a substantial investment and long-term funding commitment. Is fulfilling SSE sufficient assuming potential cost advantages? Lang (2018), Fetterly (2018) and PBO (2019) discuss challenges in implementing SSE ranging from recruitment difficulties and lapsing of procurement funds to potential acknowledged, but not explicitly included costs of negotiated pay increases to military and civilian personnel. For example, PBO (2019) estimates an annual incremental funding of $5B (CAD) to cover such wages settlements.

The Office of the Auditor General (OAG) is more blunt, concluding that the fighter force could not meet the 'government's new operational requirement, which is to have enough aircraft ready each day to meet the highest NORAD alert level and Canada's NATO commitment at the same time' (Office of the Auditor General-OAG 2018). To further illustrate the challenges, we present a simple trend analysis and projection of capital expenditures based on publicly available defense data and SSE (DND 2017) projections. Figure 5 (Panel B) shows that Canadian Department of National Defence (DND) lapsed on average, 16% of the capital budget or roughly $678 M (CAD) annually. To fulfil the projected capital spending in SSE, DND must triple its absorption rate! (Panel A, Figure 5).

This simple trend analysis confirms earlier assessments such as Solomon and Penney's (2020) that the expected SSE investments may not be realized due to procurement challenges and bureaucratic inertia. From a monetization of expected burden sharing target fulfilling the re-investment in key military assets promised in SSE is the minimum albeit, difficult target.

At the higher-end of the burden-sharing monetization spectrum, we can assess the estimated extra funding to achieve NATO's 2% goal by 2024-25 (the expected target date to achieve the spending goal). Once again, we use publicly available data from North-Atlantic Treaty Organization-NATO (2022) defense expenditures dataset, SSE (DND 2017) projections and GDP projections from the Canadian Federal Budget[13] to assess Canada's progress (Government of Canada 2022). Table 4 presents the results. For the fiscal years 2017-18 to 2020-21 we use actual data from public sources for Canadian military expenditures (Actual column) and NATO figures (also actual for the same fiscal

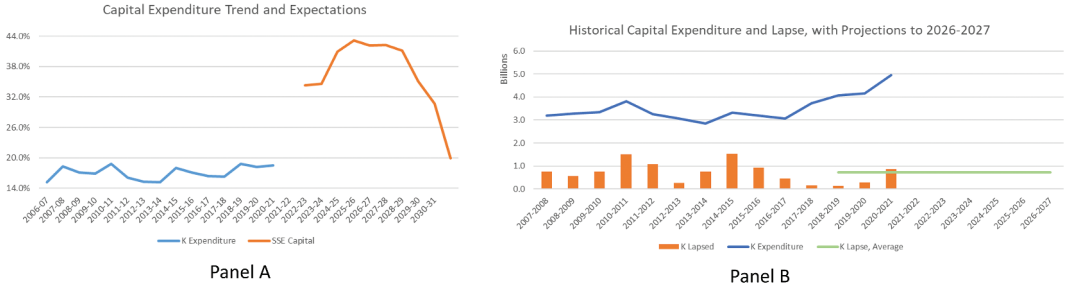


Figure 5. Projected capital spending trend: ambition versus reality.

Table 4. Achieving the 2% goal.

	Actual	SSE 2017	NATO (2022)	Budget 2022**	Other Para Military*	Projected MilEx	Projected Burden Share	Wales Summit Target
2017-18	22,877	20,682	30,761		7,884	30,761	1.42%	
2018-19	21,616	21,428	29,025		7,409	29,025	1.29%	
2019-20	22,839	21,714	29,949		7,109	29,949	1.30%	
2020-21	26,827	24,276	31,644		4,817	31,644	1.41%	
2021-22		25,314	33,674		8,360	33,674	1.39%	
2022-23		26,048		835	7,458	34,341	1.36%	
2023-24		29,879		1,243	7,748	38,870	1.48%	
2024-25		31,741		1,720	8,043	41,504	**1.52%**	13,110
2025-26		31,931		1,906	8,340	42,178	1.49%	14,457
2026-27		32,673		2,796	8,674	44,143	1.50%	14,757
2027-28		33,404			9,021	42,425	1.39%	18,832
2028-29		31,474			9,382	40,856	1.28%	22,851
2029-30		30,528			9,757	40,285	1.22%	25,970
2030-31		27,202			10,147	37,350	1.08%	31,555

* Other government department spending to conform to NATO's definition.
**Based on funding announced in Federal Budget 2022.

years). The burden share is projected using nominal GDP growth rates from the Federal Budget and additional funding promised in the budget document.[14] We apply the same growth rate to the other paramilitary spending projections.

Based on the projections, additional funding ranging from $13B in 2025 fiscal year to $32B by fiscal 3031 is required to achieve the NATO target. Alternatively, Canada needs to invest an average of $20B annually from 2024 to 25 (the target date for achieving 2%) onwards.

While the burden-benefit concordance is a useful way of assessing burden sharing in a bilateral context, the policy implications may be difficult to discern. The bounds discussed above do provide some useful discussion points on Canada's future funding decisions. The government has already stated a policy review in its 2022 budget. This review should seriously consider what force structure better protects the North American sphere and reduces the anxiety over burden sharing.

For example, Canada achieved a modest balance between burdens and benefits received in 1993. The force structure during this period displayed robust and relatively up to date equipment, force projection capabilities, with bases in Europe and the Americas, and larger personnel levels. This is one scenario to consider for future funding. Another minimum discussion point is expediting the delivery of equipment funding promised in SSE. This may require the re-writing of government procurement policies and streamlining bureaucracy. Another option is to increase the productivity of the military through substantial investment in R&D both internal and extramural.

Concluding Remarks and Future Directions

We summarize some of the key takeaways from the preceding discussion of burden-benefit measures. We use defense as a share of GDP as an input measure along with a disaggregated view of defense production (labour and capital) to focus on defense processes and delivery. We do acknowledge that the measure does not reflect outcomes or outputs in the form of security achieved. However, a measure that focuses on the use of land and systems in the protection and surveillance of the North American airspace revealed a more nuanced view. Specifically, Canada exhibits a more equal burden-benefit concordance given the large land use for the infrastructure of the DEW and NWS. Other measures such as the disaggregated view of military expenditures, however, reflected the large asymmetric power structure between the U.S. and Canada.

For example, using the relative share of military expenditures, the U.S. shoulders a disproportionate amount of the burden in the bi-lateral alliance (about 97.6% of the North American defense burden but receives about 64% of the benefits). Modifying the analysis by removing the vast Canadian coastline from the benefit measure improves the imbalance, but Canada continues to enjoy more benefits than its contribution. Canadian defense policy has always indicated the necessity of maintaining both our shared commitment of protecting the continent (NORAD) and our multi-lateral defense responsibilities (NATO). Recent studies, however, place NORAD ahead of NATO since the Arctic is the next strategic focus both militarily and economically. As such, we do a burden sharing evaluation of the select Arctic states including Canada to verify whether Canada's weak performance in burden sharing can be ameliorated.

Compared to the selected Arctic states, Canada is indeed larger and contributes roughly 47% of the defense spending. However, it also receives 64% of the benefit. It is also the only country that generates more benefits per dollar in defense spending. As pointed out by Hartley (2020) and Kim and Sandler (2020) the assumption that the marginal cost of producing defense is the same across an alliance is not valid since some countries have comparative advantage in producing defense capabilities. Although not a definitive micro-level analysis, Canada's military personnel (or labour component) seem to have a comparative advantage. A more in-depth understanding of this aspect needs to be examined by looking at operational-level effectiveness and deployed to available personnel ratios and performance.

Finally, we attempted to quantify the level of additional investment required to make Canada a viable defense partner. Our select scenarios indicate a minimum of expediting the funding and investment outlined in SSE (defense policy) to a maximum of 21B (CAD) annual investment starting in 2024-25.

The search for an appropriate output measure remains elusive but a worthwhile future project. Another useful avenue for future research involves the microscopic investigation of specific services or operational level outputs (sorties flown, etc.) to get a better understanding of where one can optimize the North American defense. Finally, a public economics perspective, such as exploring aggregation technologies, game structures, etc., may provide theoretical insights that can be further validated empirically.

Another emerging area for future research is the Arctic. This region is possibly the next strategic battleground given the implications of climate change, great power struggle among Arctic and near Arctic nations (U.S., China, and Russia). The tools and methods of the economics of alliances and demand models need to be exploited and expanded to understand the defense and security posture of Nordic and Baltic states.

Notes

1. The European Union EU steps up action to strengthen EU defence capabilities (europa.eu) Accessed May 28th, 2022.
2. See, for example, the CBC report Top military leader calls for 'accelerated' defence investments in response to Russian aggression | CBC News Accessed May 30, 2022.
3. For example, Canada's military expenditures (Mei) divided by the total military expenditures of NATO members (NATO ME).
4. We do not conduct a Wilcoxon test as the sample sizes are too small ($N = 2$ and $N = 5$ for Arctic Council)
5. https://www.oecd-ilibrary.org/science-and-technology/frascati-manual-2015_9789264239012-en Accessed May 7th, 2022
6. we would like to think two anonymous referees for their valuable comments regarding the use of land as a potential burden sharing measure. Also note that the article by Secrieru et al (this issue) provides a theoretical model that utilizes land and technology as inputs in the production of NORAD outputs that are impure public goods.
7. https://www.treaty-accord.gc.ca/text-texte.aspx?id=101003 see paragraph 12. Accessed March 16th, 2022.
8. Technically, the DEW line was operational since 1963, however, the benefit share data is only available since 1972.

9. Maintenance costs are essentially identical to the land input shares. Based on Jockel (2007)
10. Similar to the methodology adopted in Droff and Malizard (2019).
11. We acknowledge this inciteful perspective of an anonymous referee for the use of a moving average. We also use a five your average but had little effect on the overall net benefit. The results are available upon request.
12. We acknowledge the suggestion of a referee for this important aspect of Arctic Security. Future studies ought to examine the Arctic security either through a demand model to explicitly test threat response or through a burden-benefit concordance with more precise measures.
13. https://budget.gc.ca/2022/report-rapport/toc-tdm-en.html
14. The figures in Budget 2022 column (Table 3) are based on Chapter 5 of the Federal Budget 2022 and the text associated with Chart 5.1. The text indicates roughly $8.5B while the table in Chapter 5 only displays roughly $8B. We thus add the remaining difference into 2026-27 figures.

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