Global impact of national climate policy in the Nordic countries

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Abstract

Although domestic emission reductions have small global effects, the Nordic countries have engaged in ambitious policies to reduce these emissions. One rationale could be a belief that this will influence other countries also to be more ambitious. We explore various mechanisms by which small countries can hope to affect decisions about emission reduction programs in other countries. Of these mechanisms, technological advances through R&D seems to be the most viable. However, the current approach to technological development in clean technologies in the Nordic countries appears fragmented and in lack of a clear goal to influence other countries. The Nordic countries may also follow an ambitious climate policy because they want to do their share of a global effort to halt climate change. This is in line with recent research on so-called Kantian preferences. However, a Kantian climate policy does not imply that any type of climate action is morally good; rather, countries need to consider whether an action is in line with what to expect from *an ideal climate treaty*. Moreover, no action must violate or muddle with other international obligations to which the Nordic countries have committed.

1. Introduction

The Nordic countries all aim to follow an ambitious climate policy. For instance, all Nordic countries participate in the Kyoto agreement, but some of the countries have greenhouse gas (GHG) emission reduction targets for 2020 that largely overshoots what they committed to in this treaty. Now, the Paris agreement is soon to succeed the Kyoto treaty, and the Nordic countries, together with the EU, have set more ambitious targets for emission reductions than other industrialized countries such as Japan, Canada, Australia and the US, which later withdrew from the agreement.[1]

There are at least three ways in which the Nordic countries appear to apply an ambitious climate policy:

i. Some sectors face very high carbon prices
ii. The promised total GHG emission reductions exceed those of other comparable industrialized countries
iii. The shadow cost of GHG emission reductions for a range of specific climate policy measures far exceeds international permit prices

Regarding i), all Nordic countries have carbon taxes for road transport that far exceed the implicit price on emissions in other sectors. The Paris treaty is already mentioned as an example of ii). Finally, with respect to iii), there are ample examples of GHG abatement subsidies to industries that participates in the European emission trading system (ETS). The cost of these measures indicate that it would be less expensive to reduce emissions by buying ETS permits.

In this article we look for hallmarks of an ambitious climate policy. Setting ambitious GHG emission reduction targets is clearly such a hallmark. Furthermore, costly measures initiated with the purpose of promoting new, clean technology could also be characterized as an ambitious climate policy. On the other hand, applying different carbon prizes to different sectors is, in our opinion, not necessarily

[1] Measured as percentage reduction in GHG from a historical year.

particularly ambitious. There may be many reasons why politicians want to shelter some sectors from a stringent climate policy, for instance, to avoid carbon leakage.

Our main aim with the article is to uncover potential economic and/or other reasons for choosing an ambitious policy. This allows us to evaluate to what extent the current policy choices are in line with the different possible purposes of an ambitious climate policy. Note however, that we do not aim to explain why Nordic politicians have chosen the climate policies we currently observe.

The rest of the paper proceeds as follows. In Section 2 we look closer at current Nordic climate policies. It is not as evident as before that the Nordic countries pursue more ambitious climate policies than rest of the world. In our opinion, the Nordic countries are now more in line with other Western European states like Germany and England. Then, in Section 3 we propose several potential explanations for why ambitious climate policies may be worthwhile pursuing. We divide the explanations into two over-arching theory choices. On the one hand, we have explanations relying on modelling countries as only maximizing own welfare. On the other hand, we open up for theories that let countries in one way or the other take into account the welfare of other countries.

As already mentioned we will not speculate about which explanation is most probable. Rather, in the concluding section, we will consider to what extent current policies are well aligned with the different identified potential purposes of an ambitious climate policy. This section will thus serve as a type of policy advice. For example, if the purpose of Nordic politicians is to accelerate the development of carbon neutral technology, policy makers should maybe seek to coordinate their research and development (R&D) policies better. Moreover, R&D should be directed at clean technologies with a large market outside the Nordics.

Having a technological focus does not run into conflict with a moral duty to *"do the Nordic countries' share of a global effort to halt climate change".* In our opinion, this duty can be understood as Kant's categorical imperative to act "*as if the maxim of your action were to become through your will a general natural law*". One way to interpret this obligation is to *act as if an ideal climate treaty were in place.* Not all types of climate actions is consistent with an ideal climate treaty. For instance, it makes no sense to restrict all emission reductions to be carried out in the home country as long as an ideal treaty would definitely not set such a restriction. Moreover, no action must violate or muddle with other international obligations to which the Nordic countries have committed. In our opinion, some Nordic climate policy measures, in particular towards emissions in the EU ETS, do precisely that.

2. Climate policy in the Nordic Countries

2.1 Emission reduction targets

In December 2015, all the Nordic countries together with nearly all nations of the world stated their commitment to the Paris agreement on climate change. As a part of the treaty, all countries should submit their planned greenhouse gas (GHG) emission reduction, which the treaty refers to as Nationally Determined Contributions (NDCs). Concerning their NDCs, the Nordic countries teamed up with the EU, and stated that they will fulfil their emission reduction pledges together with the EU.

The EU together with Iceland and Norway committed to reduce emissions by 40% compared to 1990 levels. This is significantly more than the emission reductions Japan, Canada, Australia and the US reported to the Paris agreement. Pursuant to EU's NDC, the EU has set one target for the emission sources covered by the EU Emission Trading System (ETS), and another target for the sources outside of the ETS, the so-called non-ETS sectors. For the ETS sectors, the EU member states have a joint responsibility to reduce emissions by 43% compared to 2005 levels. Since the ETS facilitates trading in emissions permits between firms across the individual EU states, climate policies in the Nordic countries that comes in addition to the ETS will likely only relocate emissions to other EU countries, but not reduce total emissions from the ETS sectors.[2] Still some Nordic countries have additional policies for the ETS sectors, as we elaborate on later.

For the non-ETS sectors, the EU has committed to reduce emissions by 30 percent compared to 2005 levels.[3] Moreover, the rich, Nordic EU countries have agreed to do a lion's share of the emission reductions: Sweden must reduce non-ETS emissions by 40 percent, and Finland and Denmark by 39 percent, more than any other EU country. While Sweden, Denmark and Finland are EU members, Norway and Iceland are only affiliated with the EU through the European Economic Area agreement. As mentioned, both countries aim to participate fully in EUs climate policy, and we can thus treat them as EU members in this article. Furthermore, like the Nordic EU countries, both countries will likely have to reduce their Non-ETS emissions by 40% or slightly less.

All Nordic countries, except for Iceland, have ratified a Climate Change act. In all countries, the Climate Change Act states that the country should become a low emission society before 2050 (2045 in Sweden). Denmark and Finland do not explicitly define what they imply by a low emission society, while Sweden states that they will reduce emissions from Swedish territory by 85% by 2045 compared to 1990 levels. Norway's goal for 2050 is similar to Sweden's; 80 to 95% reduction of Norwegian emissions compared to 1990 levels. However, according to the Norwegian climate change act, Norway may obtain some of these reductions through the ETS. Similar emission reduction goals can also be found in other Western European states such as England, Germany and France. Note that all Nordic countries except Iceland communicated these goals as NDCs to the Paris agreement.

Concerning emission reduction targets for 2030, the Nordic climate change acts restates the common EU contribution to the Paris agreement .e.g. 40% reduction compared to 1990 levels. However, since the 30% reduction target for the Non-ETS sectors has been broken down to individual EU country level, the climate change acts deals in more detail on how the Nordic countries ought to reach their Non-ETS target within 2030. The EU is planning a scheme for trading in non-ETS emissions among EU countries, however, to date the EU has not established any institutions to organize and monitor this trading. Moreover, there is great uncertainty as to what the prices will be for a non-ETS emission permit. Analyses by for instance Aune and Fæhn (2016) and Aune, Golombek and Hallre Le Tissier (2015) suggest that these may turn out to be considerably higher than the EU ETS prices. On the other hand, according to the EU the 43% and 30% targets were set such that marginal GHG abatement costs approximately should be equalized between the ETS and the Non-ETS sectors.

As far as we can see, all Nordic countries seem to be determined to do a large share of emissions reduction in the Non-ETS sectors within their borders, and have signaled that they will only make limited use of trading with Non-ETS emission permits from EU countries. They have a number of policy measures in place that implicitly have a GHG abatement cost that far exceeds the EU ETS permit prices. Furthermore, the Nordic countries also have sectoral targets for Non-ETS emissions like biofuels blending mandates for transport fuel, targets for number of electric vehicles sold, targets for carbon capture by forests etc. All Nordic countries thus seem to follow a very ambitious policy with respect to Non-ETS emissions.

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[2] Recent changes made to the EU ETS suggest that additional emission reductions taken on by a EU ETS firm may reduce the total available amount of emission permits in the EU ETS, and thus there is not 100% leakage as usually assumed, see Perino (2018).

[3] Together, 43% reduction for the ETS and 30% reduction for the Non-ETS compared to 2005 levels, should yield a total reduction of 40% compared to 1990 levels.

2.2 Examples of policy measures from the ETS sectors

The ETS regulates all emission from the ETS sectors in the Nordic countries. Due to the gradual reduction of the amount of emission permits administered from the EU, no Nordic country needs any additional policies in order to reach the emission reduction target of 43% compared to 2005 levels. In spite of this, there are a number of additional policies in the Nordic countries for the ETS sectors. Below we elaborate on some of them:

- Separate CO2 tax on the petroleum sector: In Norway, emissions from the petroleum sector are also subject to an emission tax. The official rationale for the carbon tax is that the ETS prices were much lower than the original carbon tax. The carbon tax is adjusted with the ETS permit price to ensure that the permit price plus the carbon tax together does not fall short of the historical level of the off shore carbon tax.
- Norway's carbon capture and storage (CCS) program: Norway originally planned to build a full-scale gas power plant with CCS. However, this plan was cancelled, and a test plant costing around 5 billion NOK was built instead. Norway continues to have CCS program, and currently the government are considering three different projects: A cement factory, an ammonia factory and a waste burning facility. The two first projects would nearly eliminate emissions from ETS regulated firms, while the latter regards Non-ETS emissions. The government argues that it is necessary with early support to CCS technologies in order to get widespread diffusion of the technology. It however worrying that so few other CCS projects seem to be online in the rest of Europe.
- Support for use of bioenergy in industries: In all Nordic countries, apart from Iceland, government support the use of bioenergy for use in industries. For instance, there has been trials using charcoal instead of fossil coal in cement production in Norway.
- Extra taxation and support for using biofuels in aviation; In Norway there is a climate motivated passenger tax on flights from Norwegian territory. Moreover, fossil fuels used for domestic aviation has a CO2 tax. Furthermore, the Norwegian public company governing the airports in Norway has initiated together with other Nordic partners a program for using biofuels in aviation. There is also a proposal to introduce a blending mandate for biofuels in aviation.
- Norway has a public program by the name of Enova, which support energy efficiency and GHG abatement investments for Norwegian industry. Enova recently supported a large Norwegian aluminum manufacturer with 1.6 billion Nok in order to develop a more energy and GHG efficient aluminum smelting production line. According to press statement, the company will not seek to patent the innovation, but keep the innovation secret in fear that other firms will copy the new technological solutions.[4]

2.3 Examples of policy measures from the Non-ETS sectors

Nearly all Nordic countries has set out various kinds of GHG emission reduction targets for the Non-ETS sectors. They also have a number of sector specific policies. The EU has announced that there will be a possibility to trade with other EU countries in Non-ETS permits, however, this trading institution is not yet available.

- For example, Sweden aims to reduce emission from domestic transport by 70% before 2030. Furthermore, Finland wants to have 30 percent blending of biofuels by 2030. Promotion of biofuels both by encouraging domestic production and by increasing blending mandates are essential ingredients of both the Finnish and Swedish policies. Both countries have a large

[4] See https://e24.no/naeringsliv/norsk-hydro/hydro-aapner-milliardanlegg-i-august-toer-ikke-patentere-teknologien/24104047.

forestry sector, and producing biofuels from forests material seems to be in focus. In Norway, Enova has just confirmed their 120 million Nok support to a large second-generation biofuels plant based on forestry residues.

- Norway has maybe the most proactive policy with respect to electric vehicles (EVs) and plug-in-hybrids (PHEVs). While PHEVs have an internal combustion engine and can only run for short distances on electricity alone, EVs are just propelled by their battery. In Norway EVs are exempted from both value added tax and vehicle registration tax, which for some of the more expensive brands can make up more than 50 percent of their sales price. There exist several studies of the cost of reducing CO_2 emissions by switching from fossil cars to EVs. For Norwegian EV policy, Holtsmark and Skonhoft (2014) find that the loss in tax revenue per ton CO_2 saved is more than 1000 times the CO_2 price in EU Emission Trading System (ETS) at that time. Other studies look into marginal abatement costs and find less frightening figures, see for instance the Norwegian Environmental Directorate (2016). Still, all studies seem to show that EV abatement costs exceed the current permit prices in the EU ETS by a large amount.
- Norway also sponsors electric ferry connections. The Norwegian road authorities does this by only offering concessions on certain routes to companies that can supply a zero emission connection. The first electric ferry started to operate on one of the busiest connections on the Sognefjorden in 2015. The road authorities consider this as a success, and the goal is to have 50 ferries in operation by 2020.

3. Possible motives when states act only in their own self interest

In economic models of international climate policy, it is most regularly assumed that the state act as a monolithic entity that maximizes the welfare of a representative citizen. We will also follow this approach here; however, before we inquire further into the literature, it is worth noting that the Nordic countries are all democracies with political parties catering to different sub-groups of society. Not all citizen of the Nordic countries stands to lose on an excessive climate policy. For instance, forest owners and the paper and pulp industries in Sweden, Finland and Norway may gain on these countries' biofuel policies. A proactive biofuels policy may also be in the interest of an incumbent car company such as Volvo in Sweden. Moreover, large parts of the population may be equally well off; city dwellers working for the public sector will have less local pollution, and in exchange for higher energy prices, they may benefit from a richer state (due to carbon taxes and permit auctions). A ruling party may succeed to win the election based on these groups, and hence, enact policies that over-all reduce welfare, but for which a political minority bear the losses. Since we do not aim to explain why Nordic politicians have chosen the climate policies we currently observe, we will not explore political economy models in this paper. In the rest of the paper we will keep to the assumption that that the state act in the interest of a representative citizen.

3.1 Reduce global emissions

In Paris all countries agreed to limit the temperature increase to well below 2 degrees Celsius. On the other hand, even if all countries live up to their NDCs, the temperature increase by 2100 will be between 3 and 4 degrees (United Nations, 2017). The Nordic countries may hope to decrease this gap by increasing their GHG abatement. Looking at the current and future composition of GHG emissions between countries, it seems naive to expect that extra emission reductions in the Nordics should have any direct significant impact on global temperature levels.

First, the industrialized countries as a whole makes up a shrinking share of world emissions, and even if all OECD countries and China should take prudent action, climate change seems impossible to halt without engaging the developing countries (Hoel and Holtsmark, 2012).

Second, additional GHG emission reductions in one country could result in increased GHG emissions in other countries by so-called carbon leakage. Bohm (1993) was one of the first to point out that if some countries reduce their consumption of fossil fuels in order to reduce GHG emissions, the price on fossil fuels will go down, leading other countries to use more fossil fuels. Furthermore, a more stringent climate policy in a region could induce emission intensive firms to relocate to regions with laxer climate policies as suggested by Mæstad (2001). Thus, emission reductions in one country lead to increased emissions in other countries.

Finally, other countries may also actively change their climate policies as a response to a more ambitious policy in the Nordics. Since a warming climate likely affects every state negatively in one way or the other, every state has a private incentive to reduce emissions. Thus, even in the situation without a climate treaty, we would observe that states set GHG emission reduction goals. In the economic literature, the Nash equilibrium in emission reduction goals in this kind of non-cooperative game has been extensively studied. First, it is straight forward to show that the sum of the individual countries' emission reductions fall short of the globally optimal level of emission reduction. Second, Hoel (1992) finds that if one state becomes more ambitious, the other states likely respond with less ambitious emission reduction goals. In the language of the Nordic politicians, this is clearly not, what they hope to achieve by promoting an ambitious climate policy. Setting ambitious emission reduction goals may however spur more technological development, and as we will discuss below, this can affect other countries in a more desirable direction.

3.2 R&D policy to change the direction of technological change

R&D entails two types of market failures. First, production of new knowledge does not only benefit the ones conducting the research, but diffuses in various ways through the research community and may benefit all other researcher within the same field. This is often called the "standing on shoulders" effect, and is explicitly modelled in the economic growth literature by allowing past research make current research more efficient; see for instance Romer (1986). Second, successful research often leads to patent, which allows the researcher to act as a monopoly for a limited period of time. In spite of being granted monopoly rights, as pointed out by Arrow (1962), the patent owner is still not able to appropriate the full social surplus from her innovation. Both effects implies that the private incentives to innovate may be insufficient, and that the government can improve welfare by supporting innovation in various ways.

Economist tend to stress that innovation support should be neutral, for instance, all innovation projects should receive the same subsidy independent of whether it is a new medicine, a new way of drilling for oil or an improvement in the batteries used for electric cars. Recent research has challenged this view. Acemoglu et al. (2012) considers an economy with two sorts of inputs; dirty and clean. The dirty input leads to the buildup of a stock pollution, which eventually will cause an environmental disaster. The clean input has no such external effect, but starts being more costly than the dirty input because historically less research has been devoted to develop the clean input production technology. Acemoglu et al. (2012) then shows that under certain conditions the regulator would benefit from both an emission tax and a directed research subsidy to clean research. The reason is, as shown by Greaker, Heggedal and Rosendahl (2018), that the external knowledge spill-overs in dirty research has lower social value than the external knowledge spill-overs in clean research. To avoid an environmental disaster, the economy must stop using dirty inputs in the future, and hence, knowledge that helps improving this technology is of less value.

Most agree that in order to limit global temperature increase to two degrees Celsius, the world needs to develop a range of new clean technologies. The Nordic countries, together with the EU, seem to have as their objective to redirect research funds into clean technologies. One exception is

Norway, which also sponsors research in oil and gas extraction. The crucial mechanism in Acemoglu et al. (2012) is that as long as the current state of knowledge is higher within dirty technologies, research will tend to continue happening within these technologies due to the standing on shoulder effect. If the state of knowledge within clean technologies can be brought up to the level of the dirty technologies, the process of clean inputs taking over for the dirty inputs can start to happen by itself. Moreover, clean technologies may then displace dirty technologies without an environmental policy. Hence, technology policy could achieve what environmental policy so far has not achieved; to curb emission of carbon. Possibly, a consorted effort by the Nordic countries, the rest of the EU and a set of US states (like California) could achieve such a tipping effect. The mechanism would be that a critical mass of countries did so much clean research such that the knowledge base in clean research overtook that of dirty research. According to the model, researchers from the rest of the world would then also migrate to clean innovation, and clean technologies would increase their competitiveness towards dirty technologies forever after.

On crucial assumption in this literature is that clean and dirty technologies really belong to different knowledge bases. Greaker et al (2018) relaxes this assumption, and demonstrates that a technology policy directed towards clean technologies then loses the much of its appeal. On the other hand, recent empirical literature seems to confirm that there really exist separate knowledge bases for clean and dirty technologies, see Aghion et al (2016) for a study of innovations in the car industry and Dechezleprêtre et al. (2013) for more examples of clean technologies. Another crucial assumption is that clean and dirty technologies are readily substitutable. For instance, with a CES elasticity of substitution amounting to 10, clean technologies will displace dirty technologies at once they become competitive, and directed technology policy can alone curb emissions of carbon. With a lower CES elasticity of substitution, for instance 1.5, technology policy has to be joined by environmental policy in order to curb carbon emissions. There are papers pointing to a low level of substitution. Ambec and Crampe (2012) look at deployment of intermittent renewable power technologies e.g. wind and solar, in the electricity market. They find that due to intermittency problem, wind and solar may become complimentary to fossil technologies such as gas power, at high levels of deployment. On the other hand, the degree of substitutability may also be affected by innovation. Lazkano, Nøstbakken and Pelli (2017) studies development of electricity storage technologies, and argue that they increase substitutability between clean and dirty technologies.

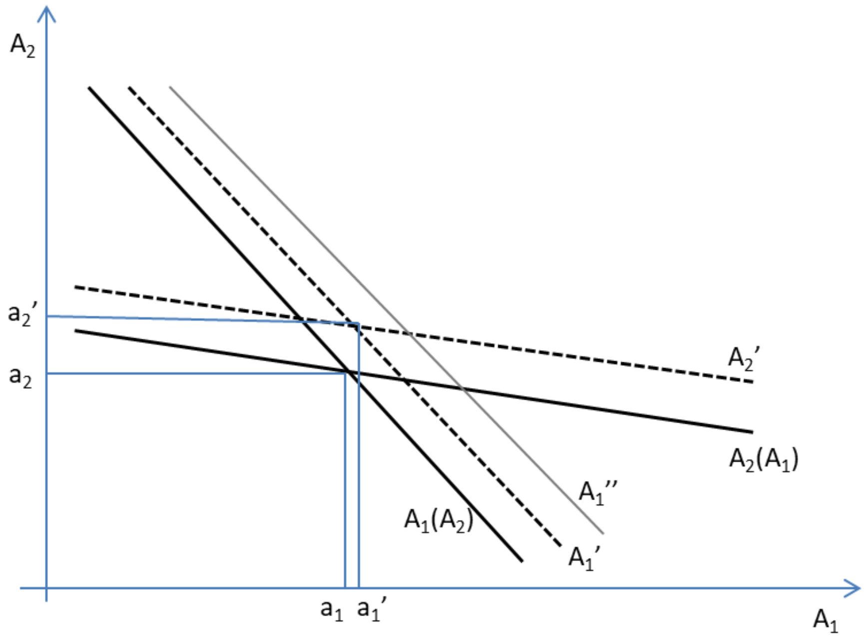
Finally, Acemoglu et al. (2012) do not define what they imply with "clean technologies". Greaker et al. (2018) speculate whether technologies based on electricity such as solar cells and wind for electricity production and batteries and electric engines for mobility could constitute a separate knowledge base. Moreover, that petroleum and coal extraction and the internal combustion engine could make up the dirty knowledge base. This is in accordance with the empirical study by Dechezleprêtre et al. (2013). Clearly, there exist intermediate cases: Carbon capture and storage is based on the dirty knowledge platform, but could all the same remove a lot of emissions. Biofuels is likewise based on the internal combustion engine and industrial processing similar to an oil refinery. Should governments therefore abstain from developing these technologies?

Whether the directed technical change literature provides countries with an avenue to influence the future course of global technological development, is not explicitly studied in the literature. There exists, however, a literature explicitly studying strategic technology policy.

3.3 R&D as a strategic investment

The Paris agreement on climate change is based on voluntary GHG emission reduction contributions by the individual countries, that is, so-called Nationally Determined Contributions (NDCs). Industrialized countries could then use technology policy strategically to influence future NDCs of other countries. Buchholz and Konrad (1994) and Stranlund (1996) were two of the first contributions looking into such uses of technology policy. Both contributions distinguish between industrialized and developing countries, and R&D investments that decrease industrialized and developing countries abatement costs, respectively. They then find that industrialized countries should over-invest in R&D that reduces developing countries' abatement cost, and under-invest in R&D that reduces their own abatement costs. The effects can be illustrated in the following figure:

Figure 1 "Strategic investments in abatement technology"



The abatement level of the industrialized country A_1 is on the X-axis, while the abatement level of the developing country A_2 is on the Y-axis. The two black, solid lines are the reaction curves of the two countries before any R&D has taken place (the steepest $A_1(A_2)$ belong to the industrialized country). The Nash-equilibrium in abatement levels (a_1,a_2) is where the two solid lines cross.

Only the industrialized country can invest in R&D. From a pure cost-minimizing perspective, the industrialized country should only invest in R&D that reduces its own costs. However, when doing so it takes into account that R&D investment lowering abatement costs will increase its own abatement contribution in the future, and consequently *lower the abatement contribution* of the developing country. This is a negative strategic effect implying that the industrialized country will under-invest in technology that lowers own costs. The difference is illustrated in the figure; the thin, grey solid line A_1'' is the abatement reaction curve of the industrialized country for a cost minimizing level of R&D effort, while the black, stippled line A_1' is the abatement reaction curve of the industrialized country for a strategic level of R&D effort.

Of pure strategic reasons, the industrialized country should also invest in R&D that lowers the abatement cost of the developing country. This will shift the reaction curve of the developing country upwards as illustrated in Figure 1 by the black, stippled line A_2'. As a result, the developing country will increase in abatement contribution, and in the new Nash-equilibrium (a_1',a_2') both countries do more abatement. Since we are dealing with a global pollution externality, this benefits the industrialized country.

A similar mechanism is studied in Golombek and Hoel (2004). In their paper industrialized countries' R&D spur abatement in other countries through technology spill-overs e.g. positive externalities. Thus, the industrialized country does not deliberately choose to invest in R&D that lowers other countries' costs. Rather, the countries invest in R&D to reduce its own cost, but as a by-product others countries' costs are also reduced. This may lead to more ambitious emission reduction pledges by other countries in the future. This would then lead industrialized countries to over-invest in R&D.

Finally, Greaker and Hagem (2013) introduce permit trade between industrialized and developing countries to the game depicted in Figure 1. Investment in both types of R&D then also has an effect on the future permit price, and not only on the emission reduction targets of the two players. For instance, investments in the type of R&D, which reduces industrialized countries' abatement costs, will also reduce industrialized countries' future payments for emission permits to the extent that they will become net permit buyers. Thus, as opposed to Buchholz and Konrad (1994) and Stranlund (1996), we may have that industrialized countries over-invest in both types of R&D. Note however that, due to the complexity of the model, the authors do not obtain unambiguous theoretical results with respect to investing strategically in abatement technologies. Instead, they run several numerical simulations in which it turns out that industrialized countries should over-invest in both types of technologies.

So far we have discussed strategic investing in R&D assuming that there exists no climate treaty that obliges countries to abate more than they do in the Nash equilibrium. There exist a large literature analyzing the prospects for self-enforcing climate treaties that involves higher levels of abatement than in the Nash equilibrium. This literature was pioneered by Barrett (1994), which found that a self-enforcing climate treaty would only attract a small sub-set of countries, and thus achieve little with respect to reducing global emissions beyond the Nash-equilibrium levels. A treaty is self-enforcing when no country wants to leave the treaty. There is however a strong incentive to leave the treaty, especially when the treaty has many member countries. A treaty with many member countries will set ambitious emission reduction targets since the externalities countries impose on each other by their emissions to a large extent become internalized. Thus, if a country leaves, it can save large abatement costs, and at the same time free ride on the remaining members ambitious reduction targets. Due to this effect, the self-enforcing treaty will consist of few member countries, which will set only modest emission reduction targets. Since Barrett's contribution (1994) this main result has been modified in many ways. For instance, McGuinty (2007) look at asymmetric countries that can promise side-payments to attract members to the treaty, and Harstad (2016) look at treaty formation as a dynamic game with technology investments that reduce the incentive to free-ride. Here we will focus on the effect of technology investment, but in a simpler way than Harstad (2016).

The key parameters in the Barrett model is b – the individual country benefit of GHG abatement – and c – the cost of GHG abatement. If c is relatively large compared to b, the Nash equilibrium emission reduction levels will be very modest, and there will be a lot to gain on a climate treaty enforcing all countries to abate more. However, as already explained, such a treaty is not self-enforcing (in the Barrett set-up). Beisland (2013) then studies the incentives fort a single country to conduct R&D that lowers the cost of abatement for all countries, that is, lowers the parameter c. If the country act non-strategic, and only minimizes its own abatement cost, the level of R&D may be modest since no country is particularly ambitious with respect to emission reductions. If on the other hand, the country acts strategically, investment will be a lot higher. The reason is that a lower c will not only increase abatement by both signatories and non-signatories to the future treaty, but also increase the number of member countries in the treaty. Thus, R&D investments can be used as a tool to increase both the breadth and the depth of future climate treaties. Other contributions also looking into this are Urpelainen (2012, 2013) and Hoel and de Zeuve (), which all are in line with Beisland's (2013) findings.

The contributions of Buchholz and Konrad (1994), Stranlund (1996), Golombek and Hoel (2004) and Beisland (2013), all have one thing in common: The R&D investments must reduce the GHG abatement cost of other countries to have a strategic effect.

3.4 Technology policies which spurs the adoption of new technologies

So far, we have discussed R&D and the market failures connected to R&D. There may also be positive externalities in the diffusion of a new technology. There are ample evidence, among others from windmills, EV batteries and solar cells, that unit costs falls as production of the technology accumulates (see for example IEA, 2000). Researchers illustrate the relationship between the unit cost and accumulated production by so-called learning- or experience curves, the names referring to the process by which the unit costs fall.

The curves show that the experience effect wears off; the cost reduction is a constant fraction per doubling of accumulated production. Clearly, if a private firm cannot appropriate all of its experience with a new technology, and this experience benefits other similar firms, we have a positive externality. It may then be welfare improving for governments to support the initial diffusion phase of a new technology. Rosendahl (2004) studies the implications for climate policy when abatement costs are declining in accumulated abatement. There are two regions; an industrialized in which experience accumulation takes place, and a developing region, which passively reaps the benefit of lower cost abatement technology. The paper shows that climate policy, represented by a carbon tax, should be more ambitious in the industrialized region than in the developing region. The results follows from the positive experience externalities, that is, every extra use of abatement in the industrialized region today will decrease future costs of abatement in both the industrialized and the developing regions.

Learning curves have an intuitive appeal: Anecdotal evidence suggests that experience will reduce costs. On the other hand, regressing unit costs on accumulated sales seem too simple to be used as a bases for policy. As sales of a product picks up, several parallel processes likely contribute to the decline in costs. R&D to lower the cost of production of the new product is not put to a halt because the product is brought to market, rather, it may be intensified. A larger market may allow for economies of scale also reducing unit costs, but here there are no positive knowledge externalities. Furthermore, the technology may benefit from R&D in other closely related fields. Nordhaus (2009) point to some of these effects, and conjectures that the estimated learning rates are exaggerated.

Network externalities may also halt the diffusion of a new technology. According to Farrell and Klemperer (2007), the consumption of a good has positive network effects if one agent's purchase of the good i) increases the utility to all others who possess the good and ii) increases the incentive of other agents to purchase the good. Recent research suggests that electric cars satisfy both i) and ii). The network externality is indirect, as it mainly results from a wider range of complementary goods and services. For example, Zhang et al. (2016) find, based on data from Norway, that access to charging stations has a strong positive effect on willingness to pay for an EV. Moreover, Li et al (2017) use data from the US and estimate a model, which combines EV sales with charging station stocks. They find that a 10% increase in the stock of charging stations will increase EV demand by 8%. Even if current climate policy has fully internalized the pollution externality of gasoline cars, the network externality could warrant subsidies to EVs and/or charging stations; see Greaker and Midttømme (2016).

While network externalities to some extent is mainly a national problem, experience effects are international. That is, if network effects are important for the adaption of EVs, a nation may find it worthwhile to subsidize EVs temporarily independent of any international effects. Accumulated experience on the other hand likely depends on the global accumulated sale of a technology. For a single, small, nation state, or even for the Nordic countries taken together, building up the accumulated experience within a technology such that costs are significantly increased seems harder to accomplish. One could still of course conjecture that the high EV sales in the small country of Norway has contributed significantly to the decline in EV battery cost. The success of the Tesla brand, which has had a large share of its sales in Norway, seems to have spurred incumbent car companies into develop their own high quality EVs.

In our opinion there are two routes in which the Nordic countries could take with respect to technological development. One route seeks to develop the broad state of knowledge within the larger category of clean technologies. Such development could include learning. However, making a difference seems to rely on cooperation within a larger unit such as the EU, or preferably, even larger units including US states, Canada, Japan etc. The second route would be to focus on areas in which the Nordic countries have expertize, and in which innovations could be expected to have a global market. This is not completely unrealistic; Norwegian off-shore oil and gas technology is used over the whole world, and Denmark is a leading windmill producer. Why not combine these two areas and seek to develop low cost floating windmills? We are sure that there exists ample other such options that we do not know about.

3.5 Technology policy to demonstrate low abatement costs

Heal and Kunreuther (2017) discusses the concept of *tipping*, *cascading* and *entrapment*. Their point of departure is that the game involving many countries negotiating a climate treaty may have many equilibriums. One equilibrium may be no treaty at all, while other equilibriums could imply broad cooperation and deep emission cuts. The equilibrium with no treaty is an example of an *entrapment*. In such a situation, a small number of players may be able to tip the equilibrium into one of the more desirable equilibriums. With *tipping* all other players follows suit, while with *cascading* other players follow one by one, each incentivizing the next player to change strategy. Heal and Kunreuther (2017) see intensified clean technological development promoted by a group of technologically advanced countries as a strategy that could set off the cascading process. This is in line with the ideas we have discussed above. In the following, we will, however, present another example of cascading based on imperfect information.

One purpose of an ambitious climate policy could be to show other countries that it is possible to have prospering society without GHG emissions. Clearly, the costs of becoming a low emissions society is currently unknown; it is hard to say how low (and fast) costs for renewable power, batteries and hydrogen-based solutions can go. Moreover, it is also hard to say how easily consumers will adapt to eat less meat, fly less etc. The following model will illustrate what we mean by showing "a good example": Assume that there are two countries only, and that they have a binary choice: Choose to become a "low-emission society" or comply with the existing climate agreement at least costs. The additional cost of becoming a low emission society is unknown to both countries. For Country 1 we assume that with probability p_1 the cost is c^l, and that with probability $(1- p_1)$ the cost is c^h. For Country 2 the costs are identical, however, we assume that the probability of a low cost c^l is p_2 with $p_2 < p_1$.

Furthermore, if both countries become low-emission societies, they will both receive a climate benefit of B, while if only one country makes this choice, the climate benefit is B/2 to both countries. We also assume that each country i has a private benefit b_i of becoming a low emission society. This could for instance be less local pollution, less dependency on oil import etc. Finally, we normalize country welfare to zero when they only comply with existing treaties at least costs. The two following conditions on the parameters will then yield the classic prisoners dilemma:

$$A1: B + b_i - p_i c^l - (1 - p_i)c^h > 0, i = 1,2$$

$$A2: \frac{B}{2} + b_i - p_i c^l - (1 - p_i)c^h < 0, i = 1,2$$

Although both countries would gain if both countries become a low emission society (A1), it is privately beneficial for each country to free ride (A2).

> In our opinion, it is likely that the countries will update their probabilities of becoming a low-emission society if they can observe the actual realization of costs in the other country. To fix ideas; assume that if Country 1 decides to become a low-emission society and costs are c^l, Country 2 will update its probability of c^l from p_2 to p_2', $p_2 < p_2'$ (while if costs turns out to be c^h, Country 2 will update to p_2'', $p_2 > p_2''$).

The following two conditions will then make it worthwhile for Country 1 to act:

$$A3: \frac{B}{2} + b_2 - p_2' c^l - (1 - p_2')c^h > 0$$

$$A4: \frac{B}{2} + p_1 \frac{B}{2} + b_1 - p_1 c^l - (1 - p_1)c^h > 0$$

A3 says that if Country 2 believed in a higher probability of low costs, it would move on its own. A4 denotes the expected welfare of Country 1 taking into consideration that if it successfully becomes a low emission society (cost is c_l), then Country 2 will follow suit.

Given that A3 holds, this game could be extended to n countries, which were ranked by their *a priori* belief about the probability of becoming a low emission society at low costs. As far as we can see, depending on the mechanism by which beliefs are updated, one country could possibly set of a cascading effect. On the other hand, one may argue that the Nordic countries are "too special" to influence other countries beliefs about what it costs to be a low emission society. Moreover, how probable is it that A3 holds? A necessary condition is of course that: $\frac{B}{2} + b_2 - c^l > 0$.

That is, "the lowest possible abatement costs" must be so low that it is privately optimal to act. We suspect that the world is not there yet despite the large advances in GHG abatement costs in recent years. This reinforces our argument that more technological development is needed.

4. Possible motives when states consider the welfare of other states

In economic models of international cooperation on climate change, researchers mostly assume that nations act in pure self-interest. If we further assume that political decision makers act in the interest of their citizens, it follows that citizens also must be motivated by pure self-interest. This is not in accordance with ample evidence from lab and field experiments that show that people tend also to consider the well-being of others when making choices. It is however hard to disentangle exactly what is driving such behavior.

4.1 Reciprocity and warm glow

Andreoni (1990) introduced the concept of *warm glow*. It implies that consumers' utility increase both from contributing to a public good and from the public good in itself. Framed in this manner, warm glow can explain observed attitudes towards the environment; recycling of garbage, voluntary acquisition of GHG emission permits when flying, participating in organized beach tidying etc. On the other hand, we find it hard to argue for ambitious climate policy measures based on warm glow. First, it is not clear whether warm glow is something you get only if you contribute to a public good by your own actions, or if the state can act on behalf of you. Second, we lack a deeper understanding of the correspondence between type of actions and the amount of warm glow. As far as we understand, Andreoni (1990) postulated the "warm glow" effect, and it is still not completely clear to what extent an underlying mechanism explains the effect. One possibility is that warm glow could be an evolutionary inherited trait that leads to better outcomes for a group as a whole. This leads us to the recent literature about Kantian preferences by among other Alger and Weibul (2016), which we will return to below.

Another mechanism that could lead to better outcomes for a group as a whole is *reciprocity.* Reciprocity refers to the mechanism that if one actor gives something to another actor, she will get something in return at a later point in time. Reciprocity has been extensively studied in the experimental economics literature. One example is the trust game: A player receives an amount of money. The player decides what share she wants to keep to herself, and what share she wants to give to the second player. The amount she gives to the second player is multiplied by some factor, and the other player decides how much to give back to the first player. The sub-game perfect equilibrium in this game is that the first player keeps all money to herself, while the socially optimal action is to give the whole amount to the second player. The literature shows that the sub-game perfect equilibrium is rarely played. The first player regularly sends away some amount, and is also receiving an amount back. For example, Croson and Buchanan (1999) find that 85 percent of the second players return more money than was originally sent. Moreover, there is a clear sign of reciprocity; the more that is originally sent, the more is the sender getting in return.

Another type of experiment that can throw light on the reciprocity mechanisms is the ultimatum game. In the ultimatum game, a player receives a sum of money and proposes a sharing rule to the other player. The other player can either approve the sharing rule or reject it. In case of approval, the sharing goes through, while in case of rejection, none of the players gets anything. The sub-game perfect equilibrium in this game is also that the first player keeps all money to herself; the second player might as well accept, as he will not get anything anyhow. Again, the literature shows that the sub-game perfect equilibrium is rarely played. The first player normally proposes a sharing of more than 20 percent to the other player, and the other player often rejects offers of less than 20 percent. That the second player rejects small offers is seen as examples of negative reciprocity, that is, players are willing to punish players with "unfair offers" even if they are hurt themselves.

There is of course a question whether the reciprocity mechanism is valid for countries trying to cooperate on limiting climate change. The experiments are carried out in stylized settings with players that act as individuals, and transferring the results to countries, acting in complicated, multi-dimensional international settings may seem naive. There exist experiments in which the agents are groups instead of individuals, which could increase the external validity *vis a vis* an international climate policy setting. Borenstein and Yaniv (1998) and Cox (2002) both find that groups give less than individuals in the trust game. However, Cason and Mui find that when groups play the ultimatum game, the most generous member of the groups tend to end up deciding how much should be offered to the second player. This indicates that it is difficult to predict the behavior of countries based on experiments with individuals. Moreover, a group in an experiment is far from a nation with a representative democracy or a nation with a ruling party.

As for warm glow, it is also important to understand the underlying cause for the observed behavior. Some, among other Fehr and Schmidt (1999), have proposed that *inequality aversion* is driving the results, that is, agents experience a loss in utility from an unjust distribution of wealth. In our opinion, it is then unlikely that other countries will reciprocate an ambitious climate policy in the Nordic countries. Ambitious climate policies set by a small country will only in the very long run and only to a very limited extent, increase the welfare of other countries. Other countries will therefore not necessary feel obliged to reciprocate.

Another possible explanation for the observed behavior is that the players in the lab experiments act *as if* they are playing a repeated game. In a repeated game contributing to a public good may be an equilibrium strategy. It is then hard to see how the lab results can be used to argue for an ambitious climate policy in the Nordic countries. Initiating an ambitious climate policy may possibly be a way of trying to establish an equilibrium in which all countries have more ambitious climate policies. However, countries must also then stand ready to punish those countries that defect e.g. do not initiate policies that are more ambitious. As far as we can see, such a tit-for-tat strategy currently plays no part in the Nordic climate policies.

Finally, reciprocity may be an inherited trait; we punish those who treat us unjust although we loose on it, and we reward those who give us favors. It can be discussed to what extent ambitious climate policies in the Nordic countries are viewed as "favors" by other countries. The developing countries are demanding that industrialized countries should do more towards climate change. Thus, in their opinion, the Nordic countries are just doing what they at least ought to be doing. In this case they will likely not trigger any tightening of climate policies based on reciprocity in the developing world. (And since developing countries do very little today, it is difficult to do less as a response to a less ambitious policy in the Nordic).

In our opinion there may be reasons for considering other countries utility when a country decides its own climate policy. This should however not be based on what the country might get back from other countries, but rather what the moral obligation of the country *vis a vis* climate change are.

4.2 Moral obligation

Another mechanism that could lead to states to consider other states' welfare is so-called Kantian optimization. According to Kant (1785) you should act "*as if the maxim of your action were to become through your will a general natural law*". Crafton et al (2017) and Alger and Weibull (2016) study the actions of people who has so-called Kantian preferences. A person who has moral preferences value every action assuming that all other persons make the same action.

This can easily be defined for pairwise interactions. Following, Alger an Weibull (2016a), let $\pi(x,y)$ denote the payoff to a consumer who plays strategy x when the other consumer plays strategy y. A consumer with Kantian preferences will then maximize:

$$U(x,y) = (1-\gamma)\pi(x,y) + \gamma\pi(x,x),$$

where γ is the individual's degree of Kantian preferences. The first term in the expression for U is a normal utility term; with $\gamma = 0$, the agent maximizes this expression *given* the action of the other consumer. In a Prisoners Dilemma game, the Nash equilibrium is then not socially optimal. The second term is the agent's utility in the *hypothetical situation* in which the other agent was to follow the action of the first agent. With $\gamma = 1$, the agent has pure Kantian preferences, and value every action by considering the hypothetical case what would happen to own material well-being if every other agent were to follow. In a Prisoners Dilemma game, agents with such preferences would lead to the socially optimal outcome.

Alger and Weibull (2016b) use the Kantian preference structure to look at a dynamic game in which people frequently meet in groups to play a public good game. They then show that preferences of the type described above with $\gamma > 0$ are evolutionary stable, while preferences with $\gamma = 0$ are not. Alger and Weibull (2016) therefore predict that Kantian preferences may be more widespread than what we tend to think.

Crafton et al (2017) study the interaction between pure Kantian agents (with $\gamma = 1$) and pure selfish agents in a game inspired by climate change. They show that increasing occurrence of Kantian players improve the welfare of both Kantian and selfish players. This is done both in a static game looking at the Nash equilibrium, and in a dynamic game looking at Markov perfect strategies.

If people have Kantian preferences, they may vote for politicians that want to take stronger action towards climate change. Greaker et al (2013) explores this idea, and asks what kind of climate policy should a Kantian country follow in a situation in which the current international climate treaty regime is insufficient with respect to reach the agreed upon goals of limiting global warming. For instance, even if all countries live up to their Paris agreement commitments (NDCs), the temperature increase by 2100 will be between 3 and 4 degrees (United Nations, 2017). The Kantian moral obligation is then, according to Greaker et al (2013), to *act as if an ideal climate treaty were in place*.

The authors operationalize this rule along three dimensions. First, the country should apply a sufficiently high carbon price for all its emissions. That is, if all other countries applied the same price, the global temperature increase would be limited to well below 2 degrees. Second, the country should ensure that their emission level constitute *a fair allocation* of emission rights. In particular, this implies that a rich industrialized country should have lower emissions than a poor developing country (in per capita terms). The authors further argue that emissions should be measured as actual emissions from the country subtracted offsets from permit acquisitions abroad. In the latter category all projects that safely reduce global emissions should be included – also the REDD+ initiatives pioneered by Sweden and Norway. In their opinion, an *ideal climate treaty* would allow for emission trading across boarders in all kinds of GHG emissions. Finally, the country should actively direct R&D funds to clean technology development. Clearly if *an ideal climate treaty were in place*, the private incentives for conducting clean R&D would be higher. In particular, the incentives would be higher for those technologies that have a worldwide application.

Even if a majority of citizens in the Nordic countries are "Kantian" (in the notion of Alger and Weibull, 2016), and they vote for politicians that choose climate policies inspired by Kant's categorical imperative, it is, however, not obvious how far you should go in this direction. In our opinion, it is the responsibility of politicians to create an internally and externally consistent Kantian climate policy. For instance, should the Nordic countries put an extra tax on emissions from firms participating in the EU-ETS (or subsidize abatement by these firms), if the EU-ETS permit price were below the ideal price? This will not lead to lower global emissions, and could be viewed by the other EU members as "muddling" with the emission trading system. Moreover, should the Nordic countries put a carbon tariff on carbon intensive imports? Again, one could argue that prices of these imports would have been higher if *an ideal climate treaty were in place*. On the other hand, introducing a carbon based tariff could be seen as against the rules of the WTO. Finally, should Norway avoid developing oil and gas fields that would not have been profitable if *an ideal climate treaty were in place*? It could be argued that an ideal climate treaty would leave it up to each sovereign state to reduce emissions from their territory, and hence emissions from the use of Norwegian oil and gas in other countries cannot be the responsibility of Norway. On the other hand, this argument is weaker, since it is not clear whether an ideal climate treaty would not involve some restrictions on coal, oil and gas exports.

In our opinion following a Kantian rule must be simple and transparent, if not it can be suspected to be motivated by other purposes. Moreover, policies motivated by the rule must not come into conflict with other obligations such as for instance the rules imposed by EU membership and WTO membership. Lastly, it is a non-strategic choice. You follow the rule because you are obliged to do it, not because the rule may have desirable effects.

5. Conclusion

We have explored various mechanisms by which small countries can hope to affect decisions about emission reduction programs in other countries. Of these mechanism technological advances are in or opinion the most viable. However, the current approach to technological development in clean technologies in the Nordic countries appears fragmented and in lack of a clear goal to influence other countries. The Nordic countries should also seek better to coordinate their technology policies both within the Nordics and in the EU in order to maximize the global impact. In particular, we have the following recommendations:

- Technological development should focus on technologies that can be applied in other countries. As shown, development of such technologies can have positive strategic effects. The R&D effort may also help building up a clean technology knowledge base, but as the concept of a "clean technology base" is not yet established, this should not be the focus when choosing projects to support.
- Electricity storage and mobility solutions seems to be crucial ingredients of a low emission society, and thus such technologies likely have a large potential for application in other countries than the Nordics. In Sweden, there are two initiatives in this direction; two battery factories are planned in Trollhettan and in Skellefteå. The Norwegian EV policy and the electric ferry initiatives should also be studied closer in order to uncover to what extent they have had positive global effects.
- Some renewable development may also be promising, for example, the floating windmills development project lead by the Norwegian company Equinor (former Statoil). This technology may have a large potential abroad, and draws on the offshore oil production expertise of Equinor.
- On the other hand, we are uncertain to what extent technologies for biofuels based on forest material will have a significant potential in other countries. In large parts of the world, deforestation is a major problem, and thus using forests for biofuels is maybe not transferable to other countries. There is also an ongoing discussion of whether using biofuels really reduces GHG

emissions. All crops has an alternative value as carbon storage, and current policies do not ensure an optimal mix between the storage value and the use value.

- We are also uncertain about the CCS ambitions of Norway. First, as far as we can see, it is not a part of a clean technology knowledge base. Second, the Norwegian projects risk being isolated events. In our opinion, they only have a positive external value if new CCS projects in other Nordic and/or EU countries follow suit. Only then can learning (experience) gains be secured.
- Emission reduction targets for the Non-ETS sectors in the Nordic countries should not be absolute with respect to the amount of emission reductions carried out at home. The Nordic countries should fully take advantage of the flexible mechanisms being provided from the EU in this sector. By applying absolute targets, the Nordic countries risk promoting technologies that are dead-ends. Interestingly, biofuels mandates and biofuels production initiatives are often backed by the argument that biofuels are needed in order for the Nordic countries to reach their Non ETS 2030 GHG emission reduction targets.

Kantian preferences may also motivate climate policies in the Nordic. In this case, we will recommend Nordic politicians to refine what it implies to implement the Nordic countries' part of an ideal climate treaty:

- It should be acknowledge that the EU already has a very ambitious climate policy, and one could argue that if the EU fulfills their Paris commitment (NDC), the Nordic countries are in fact doing their part of an ideal climate treaty together with the EU.
- In our opinion, the major uncertainty is whether the EU will succeed to reduce emissions in the Non-ETS sector by 30 percent from 2005 levels before 2030. This could require a very ambitious climate policy in the Nordic countries for the Non-ETS sectors even if they make full use of the flexible mechanisms being provided from the EU in this sector.
- Norway should consider whether its current oil and gas development policy is in line with a Kantian ideal. According to the Norwegian Ministry of Finance, oil and gas investment at the Norwegian Continental Shelf is subsidized by a favorable tax system. This may lead to development of new fields in the Arctic, which are only marginally profitable (see Greaker and Rosendahl, 2017). Thus, Norway should inquire further into to what extent it should actively seek to leave some oil and gas in the ground.

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