Nordic Council of Ministers

Nordic Perspectives on Transboundary Climate Risk

Current knowledge and pathways for action

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Preface

Climate change is projected to have devastating impacts on people and ecosystems if the world does not reach the goals set in the Paris Agreement – and significant impacts even if it does. Traditionally the focus in public discussions and policy has been on direct climate impacts such as extreme weather events.

However, there is a growing recognition that many of the more serious impacts may be indirect, cascading and cross-border. This is especially the case in Nordic countries that are both less vulnerable to direct impacts and more exposed to international connections than many other countries.

Transboundary climate risks can manifest in many different ways. For example, severe drought in one country could devastate crops, which could raise prices of imported food in another. A typhoon or a flood could damage a semiconductor factory in one country, which could limit the production of cars or computers in another. Unrest aggravated by climate-related impacts in one country could contribute to forced migration to another.

To better understand these risks and how to respond to them, the Nordic Council of Ministers' working group on Climate and Air (NKL) commissioned this study from a Nordic consortium consisting of Tyrsky Consulting, the Stockholm Environment Institute and the Western Norway Research Institute. The work was guided by a steering group with representatives from all five Nordic countries. The project approached the issue from various angles and using various tools, including a literature study, expert and stakeholder interviews and trade data analysis.

The report suggests that there is potential to deepen Nordic cooperation in analysing transboundary climate risks and addressing them. While the Nordic Council of Ministers and national governments can play a key role, building resilience requires broad cooperation with businesses and other stakeholders, both within the region and internationally. The project contributes to the Nordic Prime Ministers' vision for the Nordic region to strengthen research and development and promote solutions that support CO_2 neutrality and climate adaptation in areas such as transport, construction, food and energy.

We would like to thank the consortium and the steering group for their important work. We hope this report can inform Nordic policy-makers and business leaders in how to prepare for transboundary climate risks.

Sara Berggren, Chair, Nordic Working Group for Climate and Air (NKL)

Executive summary

The Nordic countries are widely considered front-runners in climate action. Given their location and socio-economic and political profiles, they also have relatively limited vulnerability to direct climate change impacts.

Yet there is an important aspect of climate risk that the Nordic countries have yet to fully grapple with: transboundary risks. In a highly interconnected world, climate impacts – from extreme events such as storms or floods, to gradual changes such as sea-level rise and shifting ecological zones – can cascade from country to country, transmitted through supply chains, financial systems, shared natural resources, and other international linkages.

As noted in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), the impacts of transboundary climate risks are already being felt around the world, but they are not yet well understood, much less integrated into adaptation strategies and policies.

This study, commissioned by the Nordic Council of Ministers, examines the cross-border risks faced by Nordic countries, to what extent they are already recognised, and possible ways to respond to them. The analysis draws on a literature review, an analysis of trade data, and interviews with stakeholders from national authorities, industry and research institutions.

Seven pathways for the transmission of transboundary climate risks are identified in the literature: trade, finance (e.g. foreign investments, remittances), people (travel and migration), psychological (e.g. inaction if risks are perceived as affecting only other countries), geopolitical, biophysical (through shared ecosystems and other natural resources) and infrastructure.

The Nordic countries are ahead of many others in analysing transboundary climate risks, but for the most part, they have not determined how best to tackle those risks. Stakeholders agreed that there is a need for more dialogue between governments, companies and civil society, as well as more information on the risks and their potential impacts on different sectors. It is also important to better address supply chain-related risks. Some large companies are already addressing transboundary risks, but more systematic work is needed.

International trade in goods and services is crucial to Nordic societies, affecting everything from industry, to food supplies, to healthcare systems. An in-depth analysis of the Nordic countries' trade relationships and the climate risks embedded in them identified five sectors of special interest: agriculture and food production; transport; petroleum and other energy imports; finance and investment; and machinery. Agriculture and food poses the most critical risks.

Even though the Nordics mostly trade with other relatively climate-resilient countries, several key commodities, such as soy, coffee, cocoa and fruit, come mostly from developing countries that are highly exposed and vulnerable to climate impacts. Transboundary risks affect inputs to Nordic agricultural systems (maize and soy for animal feed) as well as food industries and consumption (rice, sugarcane, coffee). If not addressed, these risks could result in some food products being

costlier or less available. The COVID-19 pandemic has highlighted the risks of heavy import dependence for all five countries.

In the near term, the Nordic countries could continue to rely on traditional approaches to managing trade risk, such as substitution and diversification – but those may not work in a world that faces multiple, accelerating climate impacts. An alternative is to cooperate on a strategy that combines an increased domestic supply of inputs; sustainability and diversification of Nordic agricultural production; and support for trade partners to help them strengthen their production systems, and thus increase climate resilience across future global food markets.

The Nordic countries differ in important ways, including in their relationship to the EU, their approaches to contingency planning, and even in how far along they are on their adaptation journey. However, Nordic action on addressing transboundary climate risks can build on their commonalities, focusing on areas where cooperation would provide the greatest added value. This includes joint research projects and shared risk analysis, for example, as well as awareness-raising and sharing tools to help public- and private-sector actors address transboundary risks.

The Nordics can also work together to raise awareness and promote collaboration in the global arena, including through alliances with strategic partners in the global South, while also integrating transboundary climate risks into their development cooperation and research efforts. Given the significant role of business in identifying and addressing these risks, another promising area is to foster public-private partnerships, actively engaging with trade associations, companies and business-affiliated research institutions.

Based on this analysis, the report highlights 10 priorities for Nordic cooperation on transboundary climate risks:

- Establish a **joint Nordic research programme** to provide a shared knowledge base;
- **Foster mutual learning** and sharing of adaptation best practices in policy and business;
- **Raise awareness** about transboundary risks among decision-makers in the region;
- **Share existing practical tools** created in the Nordics to address transboundary risks;
- Deepen Nordic **cooperation in contingency planning** around transboundary risks;
- **Coordinate Nordic initiatives** on transboundary risks in the EU and in various international forums;
- **Build alliances with partners in the global South** to facilitate mutual learning and potentially identify international measures to pursue together;
- **Engage with the private sector**, including businesses and trade associations, in discussing and planning on transboundary climate risks;
- **Integrate transboundary climate risks into development cooperation**, including research and finance;
- Develop a **joint approach to food** in the Nordics, building on the experience of the Nordic Food Policy Lab and centred on shared values and practices.

The report also identifies several additional research needs, including analysis of transboundary climate risks in priority sectors other than agriculture and food, such as energy and transport; of the roles of local, national and regional authorities in

addressing transboundary climate risks; and of risk ownership – how best to divide responsibilities and coordinate efforts.

Sammanfattning

De nordiska länderna anses allmänt vara föregångare när det gäller klimatåtgärder. Med tanke geografiskt läge, socioekonomiska och politiska profiler är ländernas sårbarhet för direkta effekter av klimatförändringen relativt begränsad.

Ändå finns det en viktig aspekt av klimatrisker som de nordiska länderna inte ännu helt har tagit itu med: transnationella klimatrisker. I en globaliserad och sammankopplad värld kan klimatpåverkan – i form av extrema händelser som stormar eller översvämningar och gradvisa förändringar som havsnivåhöjning och förändrade ekologiska zoner – överföras mellan olika länder via handel och leveranskedjor, finansiella system, delade ekosystem och resurser och andra internationella kopplingar.

Som konstateras i FN:s klimatpanel, IPCC:s sjätte utvärderingsrapport märks effekterna av transnationella klimatrisker redan runt om i världen, men kunskaperna är än så länge bristfälliga och de är inte integrerade i strategier och policyer för anpassning.

I den här studien, undersöks på uppdrag av Nordiska ministerrådet de transnationella klimatrisker som de nordiska länderna står inför, riskmedvetenhet, och möjliga sätt att bemöta dem. Analysen bygger på en litteraturöversikt, analys av handelsdata och intervjuer med intressenter från nationella myndigheter, näringsliv och forskningsinstitutioner.

Sju typer av gränsöverskridande klimatrisker identifieras i litteraturen: handel, finans (t.ex. utländska investeringar, överföring av pengar), människor (resor och migration), psykologiskt (t.ex. uppfattning av risk) geopolitiskt, biofysiskt (genom delade ekosystem och andra naturresurser) samt infrastruktur.

De nordiska länderna ligger före många andra när det gäller att analysera gränsöverskridande klimatrisker, men har inte fastställt hur de bäst ska hantera dessa risker. Intressenterna enades om att det behövs mer dialog mellan regeringar, företag och civilsamhället samt mer information om riskerna och deras potentiella konsekvenser för olika sektorer. Det är också viktigt att fokusera på risker i leveranskedjan. Vissa stora företag arbetar redan med gränsöverskridande risker, men det krävs ett mer systematiskt arbete.

Internationell handel med varor och tjänster är avgörande för de nordiska samhällena och påverkar allt från industri och livsmedelsförsörjning till hälso- och sjukvårdssystem. I en fördjupad analys av klimatrisker förknippade med de nordiska ländernas handelsförbindelser identifierades fem sektorer av särskilt intresse: jordbruk och livsmedelsproduktion, transport, energiimport, finans och investeringar samt maskinsektorn. Jordbruk och livsmedel utgör de mest kritiska riskerna.

Även om Norden främst handlar med andra relativt klimattåliga länder kommer flera viktiga råvaror, som soja, kaffe, kakao och frukt, främst från utvecklingsländer som är mycket utsatta och sårbara för klimatpåverkan. Transnationella klimatrisker påverkar insatsvaror till nordiska jordbrukssystem (majs och soja för djurfoder) samt livsmedelsindustrier och konsumtion (ris, sockerrör, kaffe). Om dessa risker inte hanteras kan det leda till att vissa livsmedelsprodukter blir dyrare eller mindre

tillgängliga. Covid-19-pandemin har visat på riskerna med kraftigt importberoende för alla fem länderna.

På kort sikt kan de nordiska länderna fortsätta att förlita sig på traditionella metoder för att hantera handelsrisker, som substitution och diversifiering – men de fungerar sämre i en värld som står inför flera, accelererande klimateffekter. Ett alternativ är att samarbeta om en strategi som kombinerar ett ökat inhemskt utbud av insatsvaror, hållbarhet och diversifiering av den nordiska jordbruksproduktionen och stöd till handelspartner för att hjälpa dem att stärka sina produktionssystem och därmed öka den klimatmässiga motståndskraften på framtida globala livsmedelsmarknader.

Det finns skillnader mellan de nordiska länderna på viktiga områden, bland annat i deras relation till EU, deras strategi för beredskapsplanering och till och med i hur långt de har kommit på sin anpassningsresa. Nordiska åtgärder för att hantera transnationella klimatrisker kan dock bygga på gemensamma nämnare, med fokus på områden där samarbete skulle ge störst mervärde. Detta inbegriper till exempel gemensamma forskningsprojekt och delad riskanalys samt verktyg för att öka medvetenheten och dela kunskap för att hjälpa offentliga och privata aktörer att hantera transnationell risk.

De nordiska länderna kan också samarbeta för att öka medvetenheten och främja samarbete på den globala arenan, bland annat genom allianser med strategiska partners på södra halvklotet, samtidigt som de integrerar gränsöverskridande klimatrisker i sitt utvecklingssamarbete och sina forskningsinsatser. Med tanke på företagens viktiga roll när det gäller att identifiera och hantera dessa risker är ett annat lovande område att främja offentlig-privata partnerskap, som aktivt samarbetar med branschorganisationer, företag och företagsanslutna forskningsinstitutioner.

Baserat på denna analys lyfter rapporten fram 10 prioriteringar för det nordiska samarbetet om gränsöverskridande klimatrisker:

- Inrätta ett **gemensamt nordiskt forskningsprogram** för att tillhandahålla en delad kunskapsbas
- **Främja ömsesidigt lärande** och utbyte av bästa praxis för anpassning inom politik och näringsliv
- **Öka medvetenheten** om gränsöverskridande risker bland beslutsfattare i regionen
- **Dela befintliga praktiska verktyg** som skapats i Norden för att hantera gränsöverskridande risker
- Fördjupa det nordiska **samarbetet inom beredskapsplanering** kring gränsöverskridande risker
- **Samordna nordiska initiativ** om gränsöverskridande risker i EU och i olika internationella forum
- **Bygga allianser med partners på södra halvklotet** för att underlätta för ömsesidigt lärande och potentiellt identifiera internationella åtgärder att samarbeta kring
- **Samarbeta med den privata sektorn**, inklusive företag och branschorganisationer, i diskussioner om och planering för gränsöverskridande klimatrisker
- **Integrera gränsöverskridande klimatrisker i utvecklingssamarbetet**, inklusive forskning och finans

- Utveckla ett **gemensamt förhållningssätt till livsmedel** i Norden, som bygger på erfarenheterna från Nordic Food Policy Lab och fokuserar på gemensamma värderingar och metoder

I rapporten identifieras också ytterligare forskningsbehov, bland annat analys av gränsöverskridande klimatrisker inom andra prioriterade sektorer än jordbruk och livsmedel, som energi och transport, av vilka roller lokala, nationella och regionala myndigheterna spelar när det gäller att hantera gränsöverskridande klimatrisker och av risk ägande och hur man bäst delar upp ansvar och samordnar insatser.

1. Introduction

As highlighted by the COVID-19 pandemic, today's world is highly interconnected. This means that climate risks can cascade across borders and around the world. Through trade, financial flows, the movement of people, and shared resources, climate impacts in one country – from extreme weather events, to slow changes in temperature or rainfall – can affect people and businesses in other countries, near and far (Hedlund et al., 2018).

Scientists call the situation where an event occurs in one country or jurisdiction, but reverberates in another, "transboundary climate risks". Some affect countries with shared borders or within the same region; others are transmitted through "teleconnections" such as global supply chains. It is important to recognise and address transboundary risks not only to address them directly, but to ensure that adaptation actions do not unintentionally shift risk from one country to another (Atteridge and Remling, 2017). Short-sighted responses can also amplify risks within complex systems such as international markets (Carter et al., 2021), a form of maladaptation.

The Intergovernmental Panel on Climate Change's Sixth Assessment Report notes with "high confidence" that weather and climate extremes are having transboundary economic and societal impacts through supply chains, markets and natural resource flows (IPCC, 2022, p. 35). Those risks are projected to increase across the water, energy and food sectors, and supply chains may be disrupted by extreme events.

The IPCC also notes with "high confidence" that climate change is causing the distribution of marine fish stocks to shift, increasing the risk of conflicts among fisheries users and the need for climate-informed transboundary management and cooperation. Similarly, changes in precipitation and water availability may affect water and energy infrastructure in shared river basins (noted with medium confidence).

Although there is a growing awareness and understanding of transboundary climate risks, significant gaps remain, in knowledge and especially in policy responses and adaptation strategies. There is still a common misperception that, as one analysis put it, "the vulnerability of rich (and poor) countries can be understood independently of their connections and interdependencies with other countries" (Benzie et al., 2016).

The Nordic countries – Denmark, Finland, Iceland, Norway and Sweden – have much in common in terms of socio-cultural, political, geographical, and natural characteristics. Their economies are small, relatively well integrated internally, and deeply embedded in the global economy. All except Iceland are ranked in the top 10 on the Global Index of Economic Openness (Legatum Institute, 2019). Imports and exports of goods and services are crucial for Nordic societies, and Nordic businesses and consumers alike rely heavily on complex supply chains and just-in-time production and delivery. All this means that to the extent that climate risks cascade through global systems, the Nordic countries are likely to feel at least some of the effects.

The Nordic countries are widely seen as front-runners in climate policy. However, the Nordics have yet to coordinate their adaptation efforts or develop a common adaptation strategy. Given their commonalities, it makes sense to work together to understand and address transboundary climate risks.

This study, commissioned by the Nordic Council of Ministers, aims to help close knowledge gaps and start building a strong shared knowledge base to enable deeper Nordic collaboration on transboundary climate risks. It draws on a review of recent literature and policy documents, a climate risk assessment based on trade-data analysis for Nordic sectors, and interviews with key policy actors and researchers across the Nordic region.

Section 2 provides a brief overview of the study methodology, then Section 3 provides an overview of the state of knowledge on transboundary climate risks, as well as emerging policy responses. Section 4 focuses on transboundary climate risks faced by the Nordic countries in particular, including the results of the trade-data analysis and a review of policy needs. Section 5 delves deeper into the food and agricultural sector, which emerged as a priority in the regional analysis. Section 6 synthesises some of the findings and highlights differences and similarities across the Nordic countries, and Section 7 provides specific recommendations for Nordic cooperation, as well as suggestions for further research.

2. Methods

2.1 Literature reviews and connected interviews

The scientific literature review for this study builds on work done in the ongoing project "Unpacking climate impact chains: A new generation of action- and user-oriented climate change risk assessments" (UNCHAIN). The project has published a broad literature review of methods for climate risk assessments (Aall et al., 2020), as well as a scientific article about transboundary climate risks in particular (Harris et al, 2022).

The study of transboundary climate risks is still relatively new, and there is not yet a commonly agreed and applied terminology, so the literature review was deliberately selective, guided by the recommendations of recognised experts within the field, and iterative. Searches for keywords such as *transboundary*, *cross-border*, *indirect*, *international*, *global*, *transnational* and *telecoupling* were used to help find relevant studies. About 30 scientific journal articles were reviewed, all of which are cited in Harris et al. (2022).

The study team also reviewed policy documents from Nordic countries and the EU that examined transboundary climate risks in some way or another. Altogether, 22 documents were examined: three for the EU, one for Denmark, six for Finland, two for Iceland, two for Norway and seven for Sweden. The documents were obtained by contacting project members; consulting relevant research institutes, agencies, or ministries in the Nordic countries; and searching online for the terms *transboundary climate risk*, *cross-border climate risk*, *national adaptation strategies* and *cascading effects*, along with the names of the Nordic countries. Searches were conducted both in English and in the languages of the five countries.

The desk research was complemented by interviews with representatives from national authorities and industry as well as researchers in the five countries. Twelve interviews were carried out in October and November 2021, as shown in Table 1. The goal was to identify issues that did not necessarily arise in policy document review, and to discuss the potential for action both at the national level and through Nordic collaboration. A list of the organisations consulted is provided in **Annex I**.

Table 1. Distribution of interviewees across countries and stakeholder groups

	National authority	Research	Industry	Total
Denmark	-	X	X	**2**
Finland	X	X	X	**3**
Iceland	X	X	-	**2**
Norway	X	X	X	**3**
Sweden	X	X	-	**2**
Total	**4**	**5**	**3**	**12**

The interviews were semi-structured and carried out online, guided by a list of questions presented in **Annex II**. Each lasted 30 minutes to 1 hour. Interviewees were not expected to answer all questions, but rather were asked to concentrate on the issues they know the best.

2.2 Trade data analysis

In order to understand exposure to future climate risk in supply chains and sectors, the study also conducted an analysis of current trade flows. The analysis integrated national toll statistics; input-output data in value added; data on the land and water footprints of traded goods; and a climate vulnerability index (ND-GAIN). **Annex IV** provides detailed information about differences between the data sets used, their strengths and their limitations.

The data analysis focused on three main aspects:

1. **Trade patterns**: Key trade partners, important economic sectors and commodity groups, as well as intra-regional trade dependencies;
2. **Climate risk**: The climate vulnerability of Nordic countries' current trading partners; and
3. **Sector risk**: Climate risks faced by specific sectors and dependency on foreign inputs.

To do so, the analysis focused on three main elements: (i) the size and composition of inputs to a sector and commodity group (in total monetary value and embedded land and water use), (ii) source countries' vulnerability to climate change and (iii) sectors' vulnerability to climate risk.

The method for the trade data analysis was adapted from the work of Lager and Benzie (2022) and the methodology expanded to incorporate the Nordic region. The data, methods and limitations are explained in detail in **Annex IV**.

2.3 Sector deep-dive: Agriculture and food production

The choice of a priority sector for closer analysis was based on insights from the literature review, the trade data analysis and the interviews. Five high-interest sectors were considered, based on four criteria: likelihood and magnitude of risk; trans-Nordic dimensions; priority given in each country, as indicated by interviews; and the availability of sufficient data. The results of the sector prioritisation were discussed with the Steering Group in a workshop in November 2021, and agriculture and food production was chosen as the sector for in-depth review.

The purpose of the sector-specific assessment was to get a deeper understanding of exposure to transboundary risk for the sector, identify options for addressing the risks, and explore opportunities for joint Nordic action and the possible roles of different actors. The sector analysis consisted of a quantitative analysis of climate risk in key traded inputs to the sector; and an interview-based analysis focused on risk awareness, ownership and options for action.

The quantitative analysis used the innovative Source Index developed by the Stockholm Environment Institute (Adams et al., 2021). The tool was used to identify climate risk flows at the system level as well as in import and export hotspots for six highly traded agricultural commodities: rice, wheat, soy, maize, sugarcane and coffee.

The action-oriented analysis was based on semi-structured interviews in January and February 2022 with 16 stakeholders in the sectors within the five Nordic countries. The interviewees included private-sector actors, key government officials, farmers' associations and experts in Nordic food systems. A deliberate focus was put on collecting perspectives and experiences from the private sector. Thus, representatives of several large food retailers, two food companies focused on grain-based products, a large dairy company, and a Scandinavian coffee roaster were interviewed. Table 2 shows the distribution of interviewees. **Annex III** presents a list of interviewed organisations.

The focus of the interviews was to understand 1) the level of awareness of transboundary climate risks; 2) how these risks are understood, identified and managed; 3) what actions or tools would be needed to better manage these risks; 4) who is, can or should be accountable, and 5) opportunities for or barriers to Nordic cooperation.

Table 2. Distribution of sector deep-dive interviewees by country and stakeholder group

	Private sector	National authorities	Farmers' associations	Research and think tanks	Total
Denmark	-	-	1	1	**2**
Finland	1	1	1	-	**3**
Iceland	1	1	-	1	**3**
Norway	2	1	-	1	**4**
Sweden	3	1	-	-	**4**
Total	**7**	**4**	**2**	**3**	**16**

3. Understanding and addressing transboundary climate risks

3.1 The state of knowledge of transboundary climate risks

The IPCC defines "climate risks" as (IPCC, 2022): "The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change." Accordingly, in this study, the potential for adverse consequences is labelled as "risk", while the potential for beneficial outcomes is labelled as an "opportunity".

Climate risks are most commonly framed from a local perspective, as the ways in which climate change impacts affect a particular community or ecosystem depend on local conditions and societal characteristics (for example, whether a place is heavily settled or rural; the main sources of livelihoods; levels of wealth; the strength of local institutions). Adaptation is therefore also typically framed from a local perspective. However, that leaves an important gap: how to handle climate risks that result from climate impacts elsewhere. In this report we call those *transboundary climate risks.* As noted in Section 2, however, several other terms are also used in the academic and policy literature, such as *transnational*, *cross-border*, *cascading*, *indirect* and *systemic*, among others (Aall et al., 2020). Figure 1 shows how in a conventional climate risk assessment, both impacts and responses are considered only within territorial borders, while in a transboundary assessment, the consideration of both impacts and responses transcends borders.

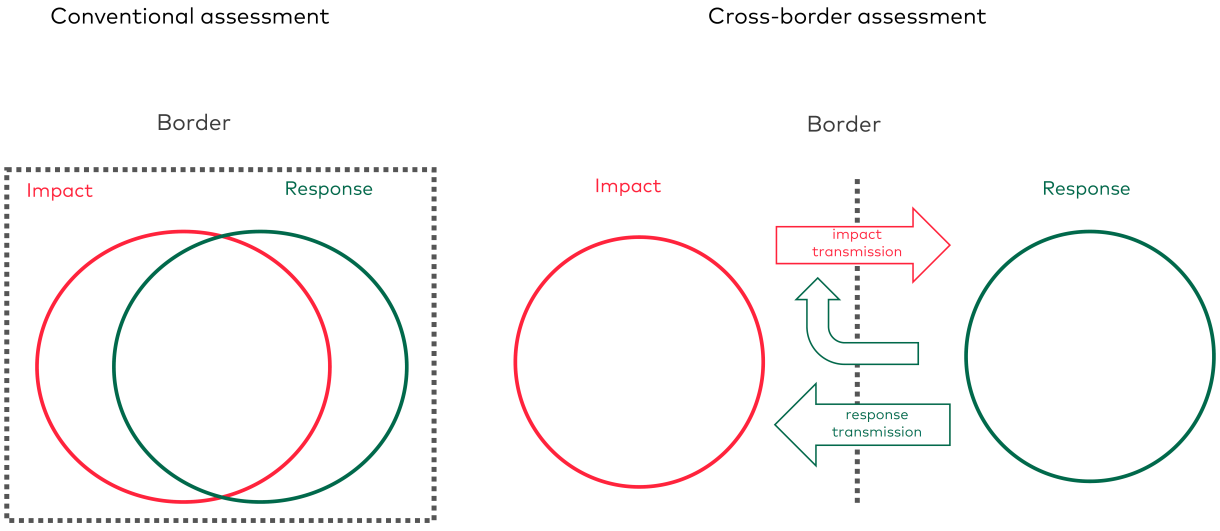


Figure 1. Conceptual framing of climate risk assessments, including impacts and responses, for conventional and transboundary risks. Source: Adapted from Carter et al. (2021).

Carter et al. (2021) identify seven pathways for the cross-border transmission of climate risks:

1. **Trade** – import and export of goods and services, as well as transport and processing sites;
2. **Finance** – the flow of capital and other assets, such as foreign investment and remittances;
3. **People** – tourism, migration or forced displacement;
4. **Psychological** - also referred to as "cognitive filter": perception and communication of climate risks and opportunities, especially as delivered by the media;
5. **Geopolitical** – impacts on international relations, resource access and strategies;
6. **Biophysical** – shared ecosystems and resources, such as mountain ranges and river basins;
7. **Infrastructure** – transport and telecommunications links.

Table 3 provides examples of commonly mentioned manifestations of transboundary climate risks and the associated transmission pathways. There are many more case studies of the biophysical pathway (and transboundary water resources in particular) than other pathways, reflecting the greater international awareness of such risks and the proliferation of governance mechanisms in response (Aall et al., 2020; Harris et al., 2022). As research and policy discussions in this field evolve, more examples may draw significant attention. The supply-chain disruptions caused by the COVID-19 pandemic may also expand awareness of transboundary risks.

Table 3. Commonly cited transboundary climate risks and primary transmission pathways

How transboundary risk is manifested	Main transmission pathway
Food security	Trade
Flooding	Biophysical
Climate migration	People
Overseas stranded assets	Finance
Security and defence issues	Multiple

The categories listed in Table 3 can overlap. For example, a severe and long-lasting drought could affect the availability of traded crops, drive migration out of affected areas, and exacerbate conflicts. The Syrian civil war is described in several studies as an example of such overlapping issues (Linke and Ruether, 2020). Indeed, concerns about climate change as a security risk triggered some of the first discussions of what are now called transboundary climate risks (see, e.g., White House, 1987).

The extent to which countries can track the development of these risks varies greatly. Flows of goods, money and people are by their very nature already monitored quite well, though mainly for other purposes. In contrast, biological risks (for agriculture, forestry, biodiversity and public health) related to invasive species and shifting ecosystems are much harder to monitor adequately, as understanding of the complexities is still spotty (EEA, 2020; New et al., 2022).

Several challenges and knowledge gaps still need to be addressed on the research side as well, as highlighted by Harris et al. (2022). First of all, there is a need for clear, commonly agreed and intuitive language with which to describe transboundary risks. It is also important to assess the strengths and weaknesses of different approaches developed so far to measure and describe transboundary risks and provide actionable information to decision-makers. Well-accepted methods are also needed to systematically identify the "ownership" of risk along the various nodes of supply chains and other pathways of transmission.

The sheer complexity of quantifying transboundary risks, and the inherent uncertainty and unboundedness of the task means it is likely to be resource-intensive to investigate and challenging to integrate with wider assessments, policies and remits. Conversely, knowledge needs to be gathered quickly to enable timely action to address risks. New types of datasets are also crucial to make it possible to profile transboundary risks at the local level, equivalent to the downscaled climate impact projections available in many countries. Decision-makers will also need guidance on best practices, both in policy and in business. Finally, more work has to be done to evaluate possible trade-offs and synergies between options for adapting to local and transboundary climate risks.

Section 6, which explores opportunities for Nordic collaboration, identifies several ways in which Nordic institutions could contribute to tackling some of these challenges and closing knowledge gaps, building on existing work by Nordic-based researchers.

3.2 Transboundary climate risks on the policy agenda

A growing number of policy documents, strategies and reports mention transboundary climate risks. Both Aall et al. (2020) and Harris et al. (2022) note that to date, more policy-driven climate risk assessments and adaptation plans have been produced at the national level than at the regional or international level – or at the sub-national level. This section examines the work done to date at different levels of governance and the opportunities for addressing transboundary risks.

3.2.1. International and regional governance

Aall et al. (2020) identify several regional and global climate risk assessments and adaptation responses that have addressed transboundary climate risks, including the European Union Adaptation Strategy, the European Green Deal, the South Pacific Regional Environment Programme, the Caribbean Catastrophic Risk Insurance Facility, and the World Economic Forum's Global Risks Report, among others.

Benzie et al. (2018) argue, however, that the best opportunities for addressing transboundary climate risks may be under the United Nations Framework Convention on Climate Change (UNFCCC) and the IPCC. Article 7.2 of the Paris Agreement outlines the global nature of the adaptation challenge and its "international dimensions". The Sixth Assessment Report explicitly mentions transboundary collaborations in highlighting the importance of "inclusive governance that prioritises equity and justice in adaptation planning and implementation" to achieve "more effective and sustainable adaptation outcomes" (IPCC, 2022, p. 35).

Aall et al. (2020) identify several mechanisms and activities under the UNFCCC that could be leveraged to address transboundary risks, including:

- Information-sharing forums such as the Nairobi Work Programme on impacts, vulnerability and adaptation to climate change, and the Lima Adaptation Knowledge Initiative;
- The Cancun Adaptation Framework, which established the Adaptation Committee, a process to formulate and implement National Adaptation Plans, and a work programme on loss and damage;
- The Marrakech Partnership for Global Climate Action to enable collaboration between governments and non-governmental stakeholders, including the private sector;
- Reporting mechanisms such as National Communications, Adaptation Communications and Biennial Transparency Reports;
- The Global Goal on Adaptation, as defined in the Paris Agreement, and the global stocktakes every five years to assess collective progress on all the Paris goals; and
- The Paris Committee on Capacity-Building.

Existing international funding mechanisms such as the Adaptation Fund, the Global Environment Facility, and the Land Degradation Neutrality Fund could potentially finance cross-border adaptation projects and incentivise the inclusion of transboundary risks in project designs.

Other international mechanisms and institutions outside the climate policy sphere also hold promise for identifying and addressing transboundary climate risks (Nadin and Roberts, 2018; Aall et al., 2020), such as the Sustainable Development Goals, the Convention to Combat Desertification, the Convention on Biological Diversity and the Water Convention. The latest UN Global Assessment Report on Disaster Risk Reduction, which emphasises systemic risks, also provides multiple examples of transboundary climate risks (UNDRR, 2019).

3.2.2. National governance

The first *national-level* policy report to specifically address transboundary climate risks was published in the United Kingdom in 2011 (Foresight International Dimensions of Climate Change, 2011). Since then, transboundary risks have been mentioned in national climate assessments in Canada, China, Finland, Germany, Kenya, Nauru, the Netherlands, Norway, Sweden, Switzerland and the United States. Some National Adaptation Plans and Nationally Determined Contributions (NDCs)

have also referenced specific transboundary climate risks (Harris et al. 2022). Separately, as noted earlier, the U.S. government has discussed international climate risks in the context of national security since the 1980s (White House, 1987).

A common challenge in addressing transboundary climate risks is ensuring policy coherence across ministries and sectors. A way to address this would be to convene cross-ministerial groups in national climate policy processes focused on business and trade and foreign policy. In that context, it would be important to clarify responsibilities and identify concrete policy implications (such as in trade priorities or economic instruments). Such groups could investigate the impact of cross-border transmission mechanisms and dependencies on countries' level of vulnerability to climate change, as well as how they might be harnessed to strengthen resilience (Benzie and John, 2015).

3.2.3. Sub-national governance

Since the adoption of the UN Framework Convention on Climate Change in 1992, the number of local authorities addressing climate change directly – first mitigation, then also adaptation – has steadily risen. Some local adaptation initiatives even pre-date the development of national adaptation strategies (Aall, 2012; Granchamp-Florentino and Rudolf, 2011).

Still, very few sub-national climate risk assessments or adaptation strategies have explicitly addressed transboundary risks. One of the first to do so was the city of Fredrikstad in Norway in 2009 (Aall, 2012). A local study showed that due to climate impacts abroad, Fredrikstad might expect an increase in "climate refugees"; higher land values for local arable land due to climate-related increases in food prices; and reduced access to low-cost imported soy-based fodder for local fish farming and meat production. The study also predicted changes in tourism and business travel that could be risks or opportunities for Norway.

The approach to analysing transboundary climate risks at the local level of governance in the Fredrikstad case was developed further and later applied to the Norwegian county of Sogn og Fjordane (Aall et al., 2017).

3.3 Key take-aways from research on transboundary climate risks

There is growing interest in transboundary climate risks in both the scientific and policy communities, as highlighted by the issue being raised both in the Paris Agreement and in the IPCC's Sixth Assessment Report. Indeed, research suggests that for some countries, transboundary climate risks could be more damaging to the economy in the long run than local climate risks – but adaptation policies and strategies do not yet reflect this.

Understanding and addressing transboundary risks can help countries adapt more effectively and avoid maladaptation. In some cases, taking a narrow territorial approach might even be futile, exacerbate systemic risks, or shift risks in a way that disproportionately affects the most vulnerable. A transboundary lens can also give

countries a different perspective on their own vulnerabilities. Although the COVID-19 crisis has shown that, as is often assumed, wealthier countries are better equipped to withstand shocks, that does not mean that they do not need to be concerned about climate change, even if they do not face the worst direct impacts.

Exposure to the transboundary climate risks depends on a country's economic openness, size, import and export dependencies, location, and access to sea trade routes. Thus, applying a transboundary perspective on climate risk can reveal new "winners" and "losers". Some countries may stand to gain – at least in the short- to medium term – from harnessing newly identified opportunities, while others may find they are more vulnerable than expected.

The Paris Agreement is built on the idea of direct territorial responsibility: countries are responsible for reducing greenhouse gas emissions within their borders, and for implementing appropriate adaptation measures related to climate hazards that occur locally. Wealthier countries are also committed to mobilising finance at a large scale to support both mitigation and adaptation in developing countries. The emerging knowledge about transboundary climate risks does not change those responsibilities, but it adds one more dimension: a responsibility to recognise the fact that climate hazards in one country can create climate risks in others – and address those risks through international cooperation.

4. Transboundary climate risks in the Nordic region

4.1 Awareness and policy responses

The Nordic countries are relatively advanced in the study of transboundary climate risks, compared with other countries in Europe and beyond. This may be because they are small countries with open, highly connected economies. Among the Nordics, Finland and Sweden have done the most to examine transboundary risks, the policy review for this study suggests.

Finland's first National Adaptation Strategy, published in 2005, noted that climate change in other countries could have repercussions for Finland. Several subsequent reports have examined different dimensions of transboundary risks – most recently, national security and migration (Erkamo et al., 2021; Hakala et al., 2021; Prokkola et al., 2021). Two earlier reports looked more broadly at how climate change worldwide might affect Finland (Kankaanpää and Carter, 2007; Hildén et al., 2016). Finland's National Climate Change Adaptation Plan 2022, approved in 2014, identifies both transboundary climate risks and opportunities (Ministry of Agriculture and Forestry, 2014).

In **Sweden**, two studies by the Swedish Civil Contingencies Agency, in 2011 and 2012, examined how climate change could affect the country's security and the preparedness (Mobjörk, 2011; Mobjörk, 2012). Even though transboundary climate risks are only briefly mentioned in Sweden's national adaptation strategy, there have been several studies on value chains, trade and various other topics (National Board of Trade, 2015; PwC, 2019; Tillväxtanalys, 2020; Ekholm and Doherty, 2020).

The Swedish National Expert Council for Climate Adaptation published its first report in 2022 (Schultze et al., 2022). It highlights how much Sweden depends on exports and imports, and that it has a low degree of self-sufficiency for several products. It warns that climate-related disruptions in supply chains "entail a risk to domestic food security, inputs for agriculture and drinking water production, as well as for other manufacturing, including the supply of medical equipment and medicines in Sweden, which entails major health threats and safety risks for Sweden" (p.560). On the other hand, it recognises global trade as an important buffer from domestic shocks, and points out that Sweden could export to other regions with increased needs. It also points to the potential economic benefits for Sweden of the opening of new shipping routes in the Arctic, which has increased the economic importance of the region.

In **Norway**, transboundary climate risks were first mentioned in a policy document in the 2010 "Green Paper" on adaptation (Ministry of the Environment, 2010). The paper mentions the "transboundary" nature of climate risks in the context of the EU, as well as the importance of good management of shared natural resources, and it warns that Norway "must ensure that the national adaptation efforts do not, directly or indirectly, exacerbate the challenges of adaptation in countries that are more vulnerable" (p. 24). In 2018, the Norwegian Environment Agency commissioned a report devoted to transboundary risks (Prytz et al., 2018). Insights from it were

included in a new Green Paper by the Climate Risk Commission (NOU, 2018). An additional report commissioned by the Norwegian Environment Agency, to be published in 2022, focuses on transboundary climate risks to the food and agriculture sector in particular.

Iceland has focused its climate efforts almost entirely on mitigation, and only published its first national adaptation strategy in 2021. It focuses mainly on risks within Iceland's borders (Umhverfis- og auðlindaráðuneytið, 2021a).

Denmark has done a substantial amount of work on adaptation, but little (or no) work has so far been done by the government on transboundary climate risks. In the review presented below, instead of official Danish policy studies and documents, analysis for Denmark is based on a report produced by EY for CARE Denmark (Ohm et al., 2019).

4.1.1. Pathways and sectors

As part of the policy review, documents were analysed to determine which of the seven risk transmission pathways described by Carter et al. (2021) were addressed (trade, finance, people, psychological, geopolitical, biophysical and infrastructure. Table 4 summarises the results. It is important to note that a checkmark only means a pathway is mentioned, not analysed in depth. As indicated, the only pathways addressed by all five countries are trade, finance and people.

Table 4. Transboundary climate risk pathways addressed in Nordic policy studies and documents

	Denmark	Iceland	Finland	Norway	Sweden
Trade	X	X	X	X	X
Finance	X	X	X	X	X
People	X	X	X	X	X
Psychological			X		
Geopolitical	X		X	X	X
Biophysical	X		X	X	X
Infrastructure	X		X	X	X

The Nordic countries' most common **trade** partners are fairly climate-resilient themselves, but commodities such as soy, sugarcane, coffee and tropical fruits come mostly from more climate-vulnerable developing countries. Climate impacts in those countries could affect crop production and/or disrupt the transport of goods, thus affecting the prices and availability of imports.

All the Nordic countries have identified risks to their **agriculture and food production sector** from this. Soy imports from Brazil, which are important for animal feed, are

of particular concern. Climate impacts in Brazil that affect soy production could result in higher prices and increased costs for livestock production and aquaculture in the Nordic region.

Almost two-thirds of Denmark's total land area is dedicated to agriculture – mainly animal husbandry and fodder production, but also cultivation of grains, vegetables and fruit for human consumption. The study for CARE Denmark notes that even though the country's agriculture sector is quite robust to 'local' climate change and highly self-sufficient, reliance on soy and other imports from tropical countries creates risks (Ohm et al., 2019). Trade partners such as Brazil, Peru, Thailand and South Africa are more vulnerable, so climate impacts in those countries could lead to scarcity and more volatile prices on imported commodities.

Iceland is largely dependent on imports of fodder (maize and soy) for the agriculture and aquaculture sector. The national adaptation strategy notes that if soy or maize production declines globally due to climate change, this will have implications on Iceland – for instance, reduced availability and price volatility (Umhverfis- og auðlindaráðuneytið, 2021a, 2021b).

Finland imports mainly from other countries in the Organisation for Economic Co-operation and Development (OECD), and more than half its imports are raw materials, goods and energy. A government study of cross-border risks found Finland was most sensitive to price fluctuations and the availability of products and raw materials (Hildén et al., 2016). Finland imports mainly from EU countries, Brazil and Norway. Prices could increase if climate change leads to a global decline in production.

Norway's trade-to-GDP ratio is about 66%, so a large share of its economy is linked to trade of commodities and services. Of its top 10 trading partners, however, all but China are high-income OECD countries and relatively climate-resilient. However, Norway also has significant trade with several countries that are more exposed to climate risks, including Poland, Turkey, Brazil and China (Prytz et al., 2018). It also imports over four times more agricultural goods than it exports (Landbruksdirektoratet, 2021), though mainly from Europe. Norway's main agricultural imports from climate-vulnerable countries are soy, meat and coffee. Aquaculture, which is Norway's second-largest export sector after oil and gas, relies on imported soy and other raw materials for fish feed, so it is exposed to transboundary climate risks (Prytz et al., 2018).

Sweden is also highly trade-dependent, and it has complex and long value chains on both the import and export sides in the food sector. Climate impacts on one link could reverberate across entire supply chains. Previous research has found that Sweden is short-sighted when it comes to the food system, and food storage is very limited (Ekholm and Doherty, 2020). However, Sweden imports much of its food from other European countries, which have a relatively low climate vulnerability (Lager and Benzie, 2022; PwC, 2019).

The **finance** pathway has been addressed explicitly in studies and/or documents in Finland, Iceland, Norway and Sweden, and indirectly in Denmark. Iceland intends to investigate how climate change abroad could affect the national economy. Finland, Norway and Sweden have already explored further and found that physical and financial assets abroad could be at risk of losing value, and the cost of insurance

could increase due to higher climate risks globally. Given their relatively low climate vulnerability, all three countries could also become more attractive places to invest; they could also export adaptation technologies to vulnerable countries.

The **people** pathway is of interest to the Nordics with regard to both tourism and migration. Even though there are numerous factors influencing where people choose to vacation, the Nordics see it as likely that tourism in the region could increase due to less snow in the Alps and high heat in southern Europe. The links between climate change, displacement and migration are complex, but the Nordic countries are anticipating more humanitarian crises. The latest IPCC report finds that climate impacts are likely to severely disrupt livelihoods, affect the habitability of some places, and increase the frequency and severity of extreme events (IPCC, 2022). Denmark, Finland, Norway and Sweden have all concluded that more international actions and cooperation will be needed, and there may be an increase in the number of refugees and asylum-seekers coming to the region. An increase in labour migration is viewed as an opportunity. Iceland has not done this kind of assessment, but intends to do so.

Only Finland has examined the **psychological** pathway in policy reports. Hildén et al. (2016) use the term "cognitive chain of influence" to describe the importance of knowledge and awareness of climate change. The cognitive chain is intertwined with the six other pathways, affecting the perception of issues and problems. One of the risks mentioned in the report is that the notion of climate change affecting other countries may lead to inaction by stakeholders from the primary production and the industrial sectors.

Both Sweden and Finland have conducted specific studies on how climate change could affect the **geopolitical** pathway and, in turn, their national security and preparedness. One Finnish study examined seven critical functions and listed potential cascading effects on them (Erkamo et al., 2021). Norway and Denmark have one report each where this is discussed (Ohm et. al., 2019; Prytz et al., 2018). Iceland has not studied this pathway. The overall picture is that climate change could result in a scarcity of resources as well as natural disasters and therefore may contribute to more conflicts. Finland, Sweden and Norway have regarded the opening of the Arctic as a possible opportunity for new trading routes. On the other hand, this could lead to more geopolitical conflict both in extracting resources and for military operations. The Nordic countries could be affected through their commitments through the United Nations and the North Atlantic Treaty Organization (NATO).

In terms of the **biophysical** pathway, the Nordics (except Iceland) have focused on how movement of people and commodities could increase the spread of infectious diseases and invasive species. The introduction of invasive species could significantly harm the agriculture and forestry sectors. This could result in more need for pesticides. Climate change could also create favourable conditions for invasive species and hence alter ecosystems. Finland additionally addresses the issue of migration of species across borders. Migration of organisms connects Finland's ecosystems to the rest of the world. About 75% of 240 bird species nesting in Finland are migratory birds. Many species of butterflies, fish and mammals also migrate across Finland's borders, connecting Finnish communities to other ecosystems (Hildén et al., 2016).

Most of the Nordics, except for Iceland, have addressed both domestic and transboundary climate risks involving **infrastructure.** For example, Finland, which has noted risks to its own energy supply and transportation infrastructure, also imports oil and gas from Russia. Damage to pipelines in Russia due to an unstable permafrost could have serious and costly consequences for both Finland and Sweden (Kankaanpää and Carter, 2007; Ekholm and Doherty, 2020). For Norway, there is a risk of damage to critical infrastructure for exporting oil and gas, as well as to transport infrastructure in general, with the potential for costly damage and disruptions (Prytz et al., 2018). Denmark is part of the ScanMed corridor, which is used to transport goods between Scandinavia and the Mediterranean and is thus of high economic importance. Ohm et al. (2019) note that vulnerability to climate change is projected to increase European transport costs.

Table 5 shows which sectors are mentioned in discussions of transboundary climate risks in Nordic policy studies and documents. Again, a checkmark means only that the sector is mentioned, not that it is analysed in depth.

Table 5. Sectors cited in Nordic studies and policy documents discussing transboundary climate risks

	Denmark	Iceland	Finland	Norway	Sweden
Agriculture	X	X	X	X	X
Aquaculture and fisheries		X	X	X	
Forestry	X		X	X	X
Energy	X		X	X	X
Transport	X		X	X	X
Security			X		X
Business and financial	X	X	X	X	X
Tourism	X	X	X	X	X
Health care			X		

4.2 Climate risk in trade for the Nordics: Results of data analysis

In this section we analyse the key components of climate risk in trade for the Nordic countries and sectors that are specifically reliant on traded inputs. The results are available at *https://public.flourish.studio/story/1028351/*. They are presented in an interactive online tool where users can go in and explore the data themselves and dive deeper into specific areas or sectors of interest. An in-depth data analysis can be found in Annex IV, and examples of illustrations from the online tool are provided in Figures 2–4.

4.2.1. The Nordic composition of trade: Input-dependent sectors and highly traded commodities

The Nordic countries have both similarities and important distinctions when it comes to the composition of major economic sectors, input dependencies from foreign markets, and climate vulnerability at source.

1. For **Denmark,** the sector with the highest share of foreign input values in 2014 was transport (about one-third of total inputs), followed by retail trade, the electrical and machinery sector, finance and investments, and construction (each one-tenth of total inputs). The most imported commodities in 2019 were machinery and transport equipment (about one-third of the total), non-classified products, chemicals and plastics, and food and live animals (10–20%).
2. **Finland**'s composition of trade looks somewhat different. The largest foreign input values are to the petroleum, chemicals and minerals sector and the electrical and machinery sector (about one-fifth), followed by finance and investments, and construction. This is mirrored in the largest commodity imports groups reported for the country: petroleum, gas, coal and coke, and electricity (one-third of all imports), followed by non-classified products, chemicals and plastics, crude materials (except food and fuel), and metal and metal products (7%)
3. **Iceland**'s commodity imports are dominated by machinery and transport equipment (about one-third of total inputs) followed by petrol, gas, coal and coke, non-classified products, crude materials (except food and fuel) and food and live animals (each around one-tenth of total imports).
4. In **Norway**, most foreign value added is concentrated in the finance and investment sector (about one-fifth of the total), followed by construction, public health, education and defence, and retail trade and the transport sector (about one-tenth of inputs each). The most imported commodities are machinery and transport equipment (40%), non-classified products, chemicals and plastics, metal and metal products, and food and live animals (6–15%).
5. **Sweden**'s composition of foreign inputs shows the largest distribution across sectors, with a fairly equal share of foreign inputs to the top five sectors: electrical and machinery; transport; finance and investments; petroleum, chemicals and minerals; and transport equipment (each about one-tenth of total inputs). Commodity imports show a more concentrated composition: machinery and transport equipment dominate, at 39%, followed by non-classified products, chemicals and plastics, petroleum, gas, coal and coke, electricity, and food and live animals (all around one-tenth of total imports).

For the Nordic countries with available data on embedded land and water use, Denmark, Finland and Sweden, the agricultural sector (including forestry and fishing) and food production sector combined account for up to half of total inputs (43–49%). Figure 2 shows a comparison of monetary inputs (value added) and land and water use per sector, using Finland as an example.

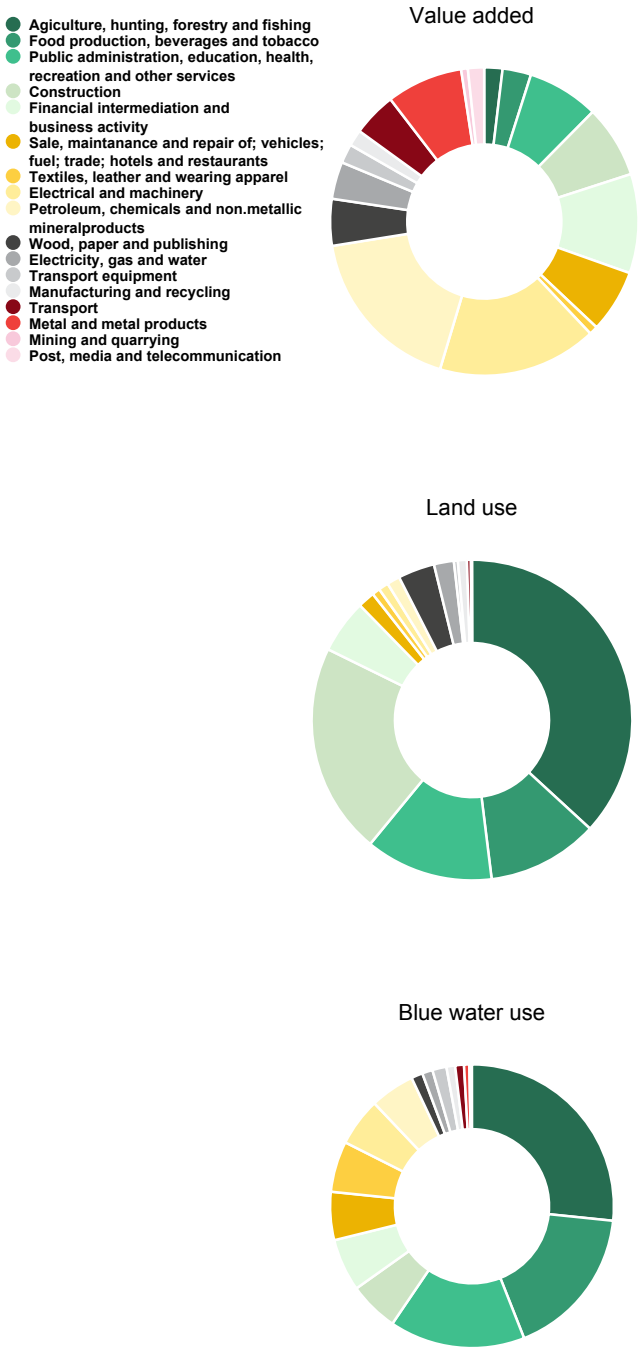


Figure 2. Inputs to Finnish sectors, drawing on multiple datasets. Inputs in monetary values (value added), total land use and total blue water use, per sector.
Source: Static image of interactive visualisation of online tool, Slide 7.

4.2.2. Climate risk for Nordic trading partners

The largest share of climate risk in trade flows in inputs to Nordic sectors according to the input-output analysis comes from the "Rest of the world" region (very high risk). This is followed by China (medium risk), other European and neighbouring countries with medium-high risk (Belgium, Poland, Russia, Italy, Ireland and Spain) and Brazil and India (very high risk), as shown in Figure 3. In addition, several smaller high-climate-risk trading partners have been identified for each country, based on results of top 40 trading partners according to toll logs, ordered by import size below:

- **Denmark:** Bangladesh (non-classified products); Greenland (food and live animals); Vietnam, Thailand, Romania and Ukraine (mixed).
- **Finland:** Taiwan, Vietnam, Malaysia and Indonesia (mixed); Congo (metal and metal products); Bangladesh, Mexico and Thailand (mixed).
- **Iceland:** Jamaica (crude materials); Vietnam and Thailand (machinery/mixed) as well as Greenland (machinery/mixed); and the Faroe Islands (food).
- **Norway:** Vietnam (machinery/mixed); Romania (machinery/mixed); South Africa, Mexico, Nigeria, Thailand and Bangladesh (mixed).
- **Sweden:** Vietnam (machinery/mixed); Nigeria (petroleum); Bangladesh and Thailand (machinery/mixed); and Venezuela (petroleum).

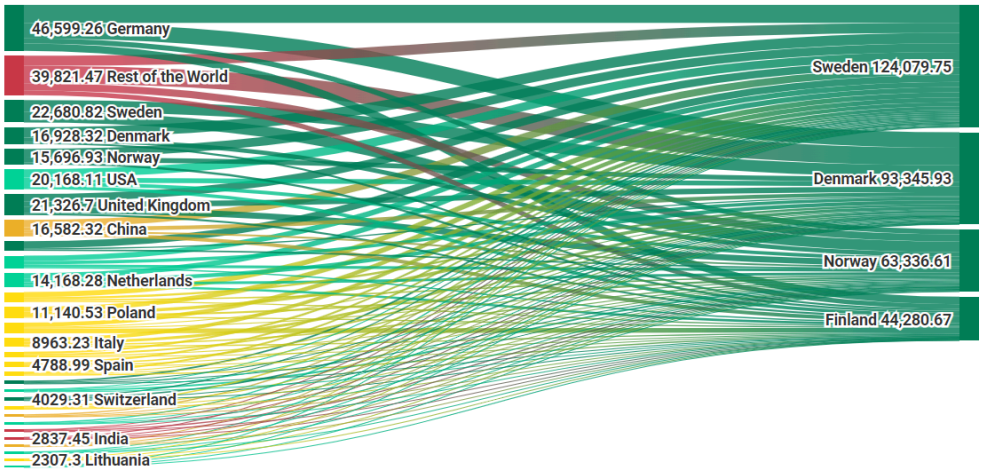


Figure 3. Overview of total foreign inputs (in value added) to four of the Nordic countries (no data available for Iceland). The colour of the country indicates climate risk, from high (red) to low (green).
Source: Static image of Slide 20 in the online tool.

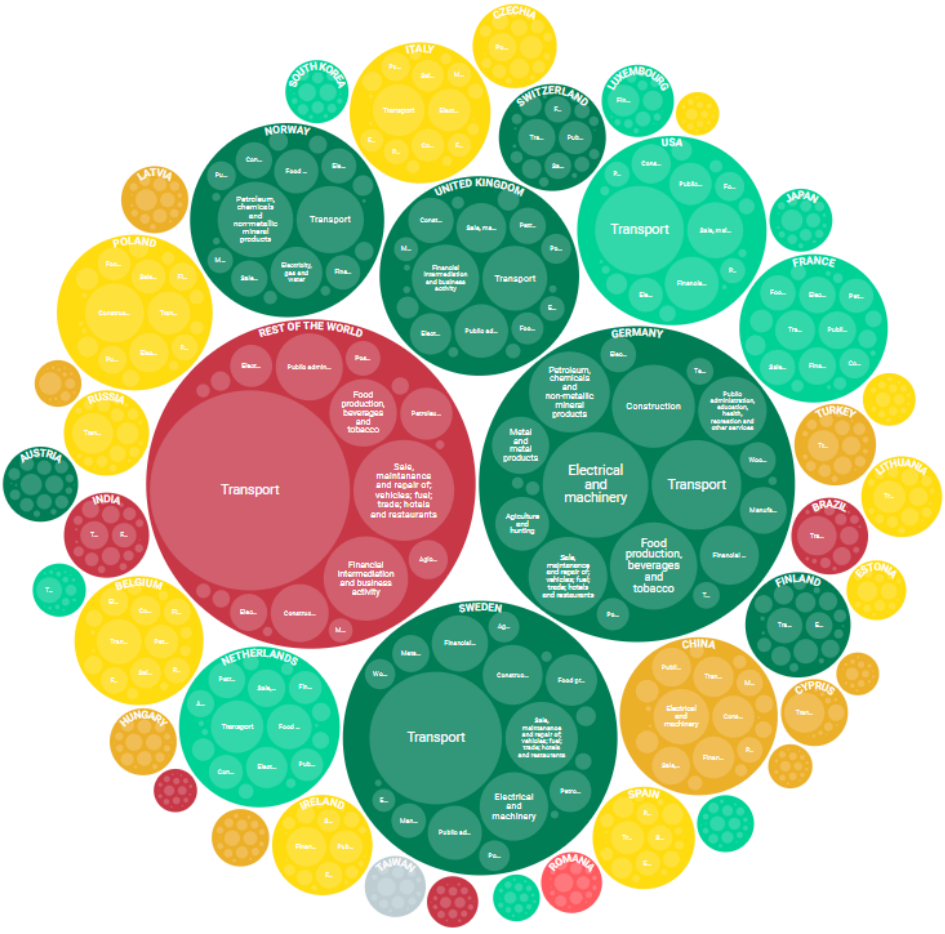


Figure 4. Climate risk in inputs to Danish sectors. Inputs to Danish sectors by country of origin, measured in value added. The colour of the country indicates climate risk, from high (red) to low (green) risk.
Source: Slide 5 of interactive tool.

4.2.3. Sectors of specific interest

Exposure to climate risk varies between sectors for the Nordic countries. A selection of high-risk sectors was made based on three main criteria: (1) climate risk content: top five sectors with content from high-risk trading partners (input-output data) and direct imports from regions with high climate vulnerability (toll statistics); (2) input dependency: sectors with more than 30% dependency on foreign inputs; and (3) land and water use (sectors with more than 20% of total land and water use). The analysis identified five sectors of specific interest for climate risk in trade across the Nordic countries, in order of importance:

- **Agriculture and food production**: High sector concentration of climate risk for trading partners, direct imports from trading partners with high climate risk, high concentration of foreign inputs to sector, and largest sector use of embedded land and water resources across the Nordics;
- **Transport:** Highest sector concentration of climate risk for trading partners, high concentration of foreign inputs to the sector in select countries;
- **Petroleum and energy imports:** High sector concentration of climate risk for trading partners, direct imports from trading partners with high climate risk,

high concentration of foreign inputs to the sector;

- **Finance and investment:** High sector concentration of climate risk for trading partners;
- **Machineries sector**: Important foreign import and input component across the Nordic countries, low sector concentration of climate risk for trading partners, direct imports from trading partners with high climate risk, high concentration of foreign inputs to sector.v

4.3 Stakeholder perspectives on progress and needs in policy and practice

Each Nordic country has a different approach to adaptation policy, which is also seen in the way policy and governance take transboundary climate risks into account. Differences in trade and security-of-supply policies also lead to differences in addressing supply chain risks. This section, based on interviews with stakeholders, complements the analyses provided above.

4.3.1. Consideration of transboundary risks in policy and governance

In **Finland**, transboundary climate risks are noted in the National Plan for Adaptation to Climate Change 2022. They have been referred to in various studies initiated by the government. These studies recognise the risks at a general level, depending on the sector and type of climate risks. There is not so much action to address transboundary climate risks directly. A possible exception is the energy sector, which has a natural transboundary connection through the Nord Pool electricity market. The key actors in policy and governance are the ministries, because the Finnish adaptation policy is based on sectoral responsibility.

The general approach to trade in Finland is an open economy, keeping borders open as much as possible. That includes having different regions around the world to supply goods and addressing problems in supply as they arise. Security of supply is under the Ministry of Economic Affairs and the Employment, but all ministries are responsible for it on their part. Relevant policies include economic affairs, transport, national risk assessments – under national security policy – and energy.

The National Emergency Supply Agency in Finland has the task of tracking and securing the supply of critical goods for the country. The agency has shown interest towards transboundary climate risk, but to what extent it leads to specific actions is unclear. The agency follows different sectors and what could happen to the supply of various critical materials, and it integrates aspects related to security of supply into national policy. The sectors that are considered critical are transport, energy and food.

Swedish policy has focused on national risks. Policy efforts for supply chain risks have primarily considered mitigation and social issues. There is a gap between exogenous supply chain risks and policy. The Swedish Credit Agency helps companies map their climate adaptation risk in exports, but not for imports. Climate

adaptation efforts for development cooperation are not motivated or directed by business needs.

In Sweden, there is no explicit work on climate risks in trade and security policy, and there is no government agency with responsibility for these issues. When it comes to value chains and climate, the focus is more on mitigation, not that much on climate risks or adaptation. The businesses are working on this mostly by themselves. On a national level, the Swedish Civil Contingencies Agency (MSB) recently mapped the security of supply and linked it to climate change. There is no clear follow-up on the study.

In **Norway**, the Environment Agency coordinates national work on adaptation. The national strategy from 2013 focuses on direct consequences and natural hazards, and doesn't specifically address transboundary climate risks. Lately, more attention has been given to transboundary climate risks and international dimensions and, as noted in Section 4.1, a report on that topic was published in 2018. The report mobilised some of the relevant sectors.

The Norwegian Ministry of Foreign Affairs recently published a strategy on adaptation in development aid work. Climate change and security is a focus area of the Norwegian government in its membership in the UN Security Council. The Norwegian Directorate for Civil Protection has made different scenarios for Norway, climate change being part of areas such as food security and supply of medicines. Transboundary climate risks are mentioned in those contexts. There is ongoing research on the topic.

The Norwegian government already has some concerns around supply chain risks, but it has not yet addressed them. Transboundary climate risks could be part of the analysis, reporting and taxonomy of adaptation. Being a well-functioning and open economy, Norway is entirely dependent on international and European supply chains. If there are shutdowns in any supply chains, they could severely affect the economy.

In **Denmark**, the work on adaptation mainly focuses on the local level. At the national level, an adaptation plan is under preparation, but transboundary impacts are not included. There is some cooperation across borders with neighbouring countries on flood control and emergency services. As noted in Section 4.1, transboundary climate impacts have not been discussed much in Denmark, as no urgent issues have arisen so far. There has, however, been discussion about energy supply and the potential for further Nordic collaboration.

Iceland's new adaptation strategy mainly focuses on local effects, but the need to consider transboundary impacts is mentioned in connection with immigration, food production and the business sector. No analyses of transboundary risks have been carried out yet. The focus in Iceland is at the moment on awareness-raising in different sectors and integrating consideration of transboundary climate risks into policies. The Ministry of Environment and the National Knowledge Centre on Climate Change Adaptation at the Icelandic MET office will be responsible for coordinating the work.

Because Iceland is an island, there is a historical awareness that value chains need to be resilient regarding important goods. Food security is considered very important, but interviews did not reveal whether actors link it to climate risks. There is also a national security strategy that mentions climate change, but not transboundary climate risks specifically.

4.3.2. Key improvements needed in policy and governance

Stakeholders identified three priorities for improving how the Nordic countries address transboundary climate risks:

Awareness-raising and dialogue: Interviewees said improved awareness is needed on transboundary climate risks and what they mean for each sector. Transboundary risks should also be recognised in disaster risk management and security policy. Potential disruptions to value chains and other economic activities should be considered as serious risks, with resources allocated to addressing them. In that context, they said, there is a need for dialogue between government, civil society and other actors. The government has an important role in educating different actors on transboundary climate risks and providing an overview of adaptation.

Building a knowledge base: Stakeholders said a common knowledge base is needed, including mapping the risks and their costs, and recognising possible cross-sectoral effects. More knowledge and tools are also needed to support analysis and to better identify indirect risks. They said transboundary risks should also be part of broader national climate risk and vulnerability analyses, as this might make it easier for different sectors to address them. A specific question to analyse is what transboundary climate risks mean for the security of supply in different sectors.

Actions to support countries of origin: Several interviewees said more efforts should be made to support the countries facing direct climate impacts associated with transboundary risks to the Nordic countries. This can be addressed through development cooperation, for instance.

Stakeholders also said that national adaptation policies and policies to address supply chain risks should be integrated with each other.

4.3.3. Lessons learned from the pandemic

The interviewees pointed out that the COVID-19 pandemic demonstrated how risks that seem remote can actualise. We have noticed how fragile the global supply chains and value chains are to abrupt shocks. Both governments and corporations should improve the resilience in all Nordic countries. There is some evidence – for example, in Sweden – that companies that have noticed how unprepared they were developing more flexible supply chains to ensure that they will have supplies also in times of abrupt changes.

The pandemic demonstrates the diversity in responses within the Nordics as well as the missed opportunities of learning and working together. Externally induced changes do not occur simultaneously in all countries. The ones that are impacted first can share with others lessons learned to facilitate the development of good practices.

One important lesson from the pandemic is that it is worth assessing whether policies or underlying legislation have hindered the ability for states to react in the best possible manner. This is worth considering before potential new crises occur.

4.3.4. Consideration of transboundary climate risks in business practice

There are differences in the extent to which businesses address transboundary climate risks across the Nordic countries. Generally, larger international corporations address these issues more than small and medium-size companies. Many large businesses are pan-Nordic.

How climate risks are handled depends on the size and type of a company. Some have a separate planning system for climate risks, or climate risks may be addressed as part of a more holistic strategy or corporate risk planning. In larger corporations, there are chief risk officers and strategy units, either on the corporate or the business unit side, to address these types of questions. Larger corporations also have investors who require actions on climate risk mitigation. In small and medium-size companies, it is more heterogeneous whether climate risks are being specifically accounted for.

The **Finnish** Innovation Fund Sitra has built a climate risk assessment framework for corporate use (Sitra, 2016). The tool has helped corporations to recognise their limited understanding of transboundary climate risks. There is no data on the effect of the tool, nor has there been a comprehensive assessment. However, a few companies have reported that it has improved their thinking and helped to refine their planning in sectors such as utilities, manufacturing industries and consumer staples. The Confederation of Finnish Industries commissioned a report on climate impacts to Finnish businesses (Deloitte, 2020). It highlights the key cross-border climate impacts both in policy and directly in business. It is a good tool for companies to begin with their own more detailed climate related risk planning.

In **Sweden**, transboundary climate risks have been identified within the business sector, but not all businesses are aware of the issue. Larger companies in sectors with long and complex supply chains are farthest along in this respect. They work according to the cascade method, putting demand on suppliers and the other suppliers down the chain. Swedish businesses have identified their main risks in a preliminary mapping. It will be up to specific business sectors and companies to dig deeper. It is difficult to know what risks companies have identified, and there is a need for more transparency. The risks Swedish companies have identified are usually only for the first level of suppliers, which often means another European company. However, the main climate risks are usually further down the supply chain. The COVID-19 pandemic showed that some companies, at least in the food and coffee sectors, were relying too much on one supplier. Now they are buying at a bit higher price to diversify risk.

In **Norway**, transboundary climate risks are not commonly addressed by businesses, but the topic is beginning to gain more attraction. There has been a demand for some years from the national capital market to push addressing transboundary climate risks in more prominent companies. The trend is moving away from specifically focusing on climate change, but instead taking a broader risk perspective.

In **Denmark**, companies are more aware of Denmark's sensitivity to rising sea levels and are beginning to plan their facilities for the future. However, they are mainly focusing on their own production, and on supply chain security on a broader scale. In Iceland, transboundary climate risks are not yet considered in business practice.

4.3.5. Key improvements needed in business practice

Interviewees identified three main priorities for improving how transboundary climate risks are addressed in business:

Integrate transboundary risks into risk assessment and give it high enough priority: Transboundary risks should be considered as a part of the various supply chain risks, and they should be addressed at a high enough level in all companies.

All companies should consider transboundary climate risks: The more dependent the company is on a specific product from a specific region, the more carefully it should consider how to address the risks. Each company should do an easy and quick first test of whether climate risks are important, meaningful or material for the company, a "yes or no" type of assessment. After that they should decide whether they need to dig deeper to understand the risks at a more detailed level.

Support smaller companies in longer value chains: They may not have the capacity for this kind of analysis, but it is important for them to be able to do it.

The interviewees identified two alternative ways to address supply chain risks. First is to consider alternative areas for sourcing or alternative trade routes. The second is to help countries where the risks may materialise to be able to cope better with the conditions. It might be worth thinking of ways to help the different parts of the supply chain, either by providing know-how, or through investments to make the supply chain more resilient. For businesses it would mean investing on site to help suppliers deal with risks.

With regard to who is responsible for making these improvements, the interviewees said that national authorities should provide tools and information to improve the knowledge base for each actor. It is up to businesses to consider risks related to their own supply chains. It should be a board-level issue in all companies. For some key sectors and products, governments might have to intervene and make the companies act – for example, to keep extra stocks of medicines. When addressing supply chain risks, some elements could be taken forward in development cooperation, and some would be more company-driven**.**

4.3.6. Needs for Nordic cooperation

The needs for Nordic cooperation in policy identified in the interviews cluster around building and sharing knowledge, policy coordination, value chains and contingency planning.

The interviewees consider that Nordic cooperation could help in understanding how transboundary climate risks can manifest in the different countries. There is a need for creating systems for sharing knowledge. Nordic countries can create systems to inform one another if they identify an impact that would affect another country. Experiences could be shared also in specific sectors. Nordics could share best practices and lessons learned on, for example, what policies have worked best for each country. Also, tools or guidance developed in one country could be shared with others. The reports produced in each country should be translated to facilitate knowledge exchange.

The interviewees also see a need for policy coordination in areas such as energy and

transport. A joint Nordic climate risk preparation strategy could be formulated. One interviewee mentioned that the Nordics should also be united to promote the necessary changes in EU legislation.

Several interviewees pointed out that significant institutionalised cooperation already exists within different sectors – for example, the Nord Pool market in the energy sector. No new institutions are necessarily needed, but the existing ones should be challenged to reflect on these issues. Awareness-raising and concrete discussions on the specific characteristics of each sector and the risks are needed. In the field of development cooperation, there could be an exchange of views, possibly leading to some joint activities.

Nordic cooperation on value chains would help to avoid duplicating work. It would be useful to study more thoroughly the value chains, products or services that are similar between Nordic countries. It could be beneficial to develop a better evaluation of policies for resilient supply chains, sharing best practices and stronger networks between experts in the field.

It would also be helpful to look through contingency planning and see whether Nordic collaboration would benefit countries. There is already cross-border collaboration between Norway and Sweden as well as Sweden and Finland. There might be something to learn from both these examples, and from the contingency and emergency drills between the Danish and German authorities. Prognoses and notification or alarm systems are an important topic for Nordic collaboration, especially related to the countries with shared borders and in relation to contingency work.

According to the interviews, it would be efficient to pool resources also in the business sector. This could cover understanding global climate risks and conducting analyses, jointly looking at alternative supply chains or even creating stocks together. Broader networking and information exchange might also be useful.

It should be remembered that many of the big businesses are Nordic already – for example, in the banking, pulp and paper and steel industries. However, not everybody is sure whether the cooperation should be at the Nordic, EU or global level. The largest risks are often situated outside the Nordic suppliers.

Stakeholders said governments and businesses should act together to support better responses to crises. It is mostly up to businesses to initiate cooperation if it is about their value chains. Businesses should also be involved in any cooperation concerning their sector.

4.4 Selection of the priority sector

As outlined in Section 2.3, a shortlist of priority sectors was identified through the literature review, and then they were analysed along different dimensions of risk to select one sector for a deep-dive. Table 6 shows the shortlisted sectors and summarises the analysis that led to the choice of agriculture and food production as the sector for further analysis. Given the significant risks in energy and transport, however, those sectors should be considered for future studies.

Table 6. Risk and priority matrix used to select a priority sector for a deep-dive analysis

Sector*	**Climate risk** (trade analysis)				**Data and method availability**
			Sectors of high priority	**Trans-Nordic dimension of risk**	
	Likelihood	Magnitude	No. of mentions in interviews	Intra-Nordic trade	
Agriculture and food	High: high sector concentration of climate risk for trading partners and direct imports from trading partners with high climate risk	High: highest land and water use, high concentration of foreign inputs to sector	4	High	High availability of data and methods
Energy**	Medium: petroleum and energy imports have a medium high sector concentration of climate risk for trading partners	High: direct imports from trading partners with high climate risk, high concentration of foreign inputs to the sector	3	High	Low: novel field of research
Transport	High: highest sector concentration of climate risk for trading partners	Medium: high concentration of foreign inputs to sector in select countries	2	High	Low-medium: maritime and land transport data available, methodology not yet developed
Business and financial	Medium: medium sector concentration of climate risk for trading partners	Medium-low: medium to high concentration of foreign inputs for select countries of the Nordics	2	Low	Medium: growing evidence base on exposure to climate risk
Tourism***	Not a sector of specific interest based on the trade analysis		1	Low	Medium-low: Various studies available on changes in tourist flows. Limited knowledge of the extent of behavioural changes of consumers.

* Comparison of sectors that were identified in at least 4 of the 5 Nordic countries according to the literature study.
** Identified gap: Trade data analysis and reviewed policy documents consider climate impacts to current social and technological systems. For the energy sector, transition risk and climate impacts on future systems will need to be considered.
*** Opportunity rather than risk: weak evidence base.

Section 5 presents the deep-dive into the food and agriculture sector, but first, the remainder of this section presents a brief overview of risks and the state of knowledge in the priority sectors that were not chosen.

For the **energy sector,** a knowledge gap has been identified in relation to future climate risk. The policy documents reviewed and the data analysis consider climate impacts to current social and technological systems, but not transition risks (in the energy sector, moving away from fossil fuels) or risks to future, different systems. This is a methodological limitation overall, but it is particularly important in the

energy sector. The policy documents mainly focus on supply risks for oil and gas tied to climate change. As Nordic and global energy systems transition away from fossil fuels, other dependencies, relationships and climatic conditions will come into play. The overall electrification of society strongly increases the demand for minerals for batteries, often from locations with elevated climate impact risks, with hitherto few local adaptation efforts, as well as geopolitical risks. The increasingly integrated electricity market of the EU+ may also entail a larger economic risk through price increases.

Transition risks also need further consideration in the **transport sector**. The transition risks could add pressure throughout distribution and supply chains, leading to price increases. Climate change can lead to increased frequency of storms and more difficulties in navigating seaways, droughts, floods, landslides and extreme heat can disrupt or damage infrastructure crucial to Nordic or global transport corridors and hubs for imports and exports. Increased global demand for goods will further strain transport systems. These interacting risks warrant more in-depth study.

The challenge with **tourism** in the Nordic countries is that different factors point in different directions. During summertime, the number of visiting tourists may go up, as summer temperatures elsewhere are increasingly too hot. Nordic people may also decide to spend more holidays in the region, with the desire to reduce emissions as a further incentive. The prospects for winter travel are even less sure, as snow packs are declining elsewhere in Europe as well. Nordic countries will have some degree of competitive advantage in this respect, but changes in winter tourism are highly sensitive to behavioural changes. This theme certainly needs more study, not the least because the sector needs more guidance on how to anticipate changes, with sufficient differentiation by region and market segment.

The significant role of biomass in the green transition, combined with the growing significance attached to the role of carbon sinks, means that the **forest sector** merits ample attention in the Nordic countries, also in the context of transboundary climate risks. The transboundary risks in this case run via biophysical links (migrating pests, invasive species) as well as via trade links of raw wood sourcing, which may be disrupted by biophysical risks or extreme weather conditions in the sourcing countries. Alongside the wood sourcing run choices made in domestic versus foreign sink enhancement and emerging emission compensation markets. In turn, these outcomes could affect the achievement of national emission targets. Hence the monitoring of climate policy costs should also include these risk factors.

5. Sector deep dive: food and agriculture in the Nordics

5.1 Climate risk in Nordic food trade – the data

Climate risk in the food sector was studied using trade data and models of climate impacts to future yields of six key global agricultural commodities: maize, rice, wheat, soy, sugarcane and coffee. In the Nordics, maize and soy are primarily used as inputs to agriculture as animal feed, whereas rice, wheat and sugarcane are predominantly consumed directly. Coffee differs from the other crops presented in this analysis, as it represents a luxury good, rather than a staple food. Nonetheless, it is of high interest for the Nordics, who are among the most coffee-consuming people in the world.

Risk is in this analysis to be understood as a combination of a crop's predicted yield losses due to climate change, how important that trading partner is to the Nordic country, and the domestic production of that crop. The higher the predicted decline in yield, and the more dependent a country is on that specific bilateral trade flow, and the smaller the domestic production, the higher the risk. In reverse, opportunities represent trading partners with a predicted increase in yield with a high potential importance for Nordic bilateral trade. Vulnerability in the sense of "societal change" is not considered in this particular analysis. For an in-depth explanation of the methodology, see Annex IV.

To contextualise the climate risk findings, the first graphs display the size of imports of each crop, including embedded consumption (Figures 5 and 6). "Embedded" inputs for domestic consumption in the food system are commodities that are not consumed directly, but rather are used as inputs. An example is a consumer in Sweden, buying German-produced sausages, containing Polish pork from pigs fed Brazilian soy. The soy embedded in that production chain is included in the Swedish embedded consumption of Brazilian soy. For wheat, the domestic production, exports and imports are shown in depth in Figure 7. This is because wheat is the only crop included in this study that the Nordic countries produce domestically in large volumes.

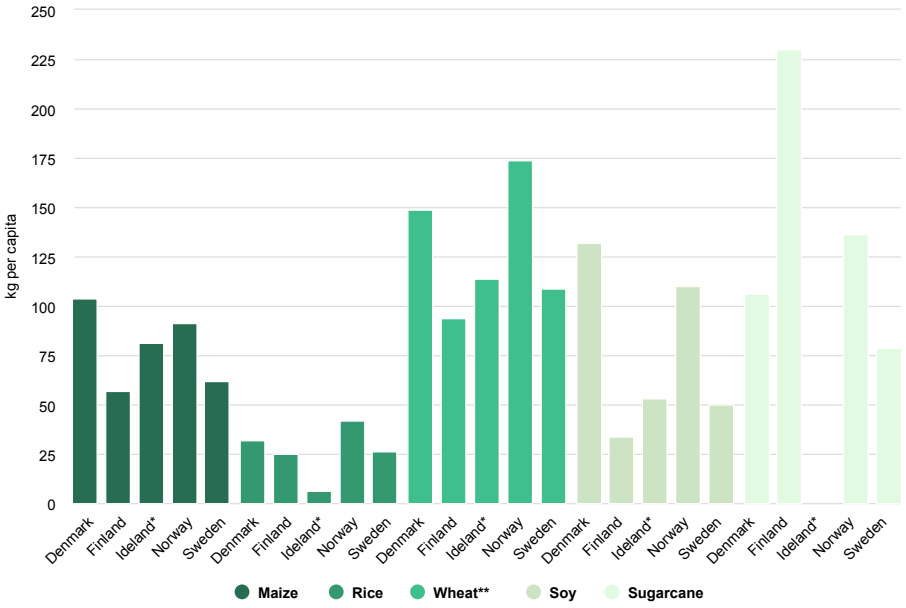


Figure 5. Total embedded inputs of maize, rice, wheat, soy, sugarcane and coffee for domestic consumption in the five Nordic countries, in kilos per capita.

*Data for Iceland should be read with caution – they are the best available data, based on FAO agricultural estimates for 2020. The data represent bulk imports and do not account for embedded inputs.

**For wheat, see also Figure 7 for a comparison between input shares, domestic production and exports.

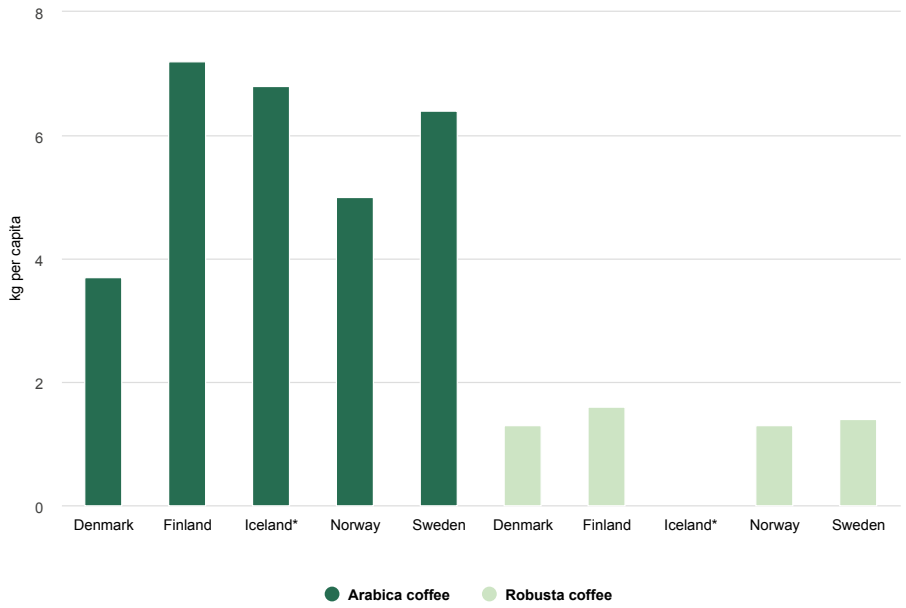


Figure 6. Total imports of coffee, in kilos per capita.

*Data presented for Iceland is aggregated coffee imports, not distinguished between the Arabica and Robusta beans. Total imports represented in the Arabica diagram. Data for Iceland should be read with caution – they are the best available data, based on FAO agricultural estimates for 2020.

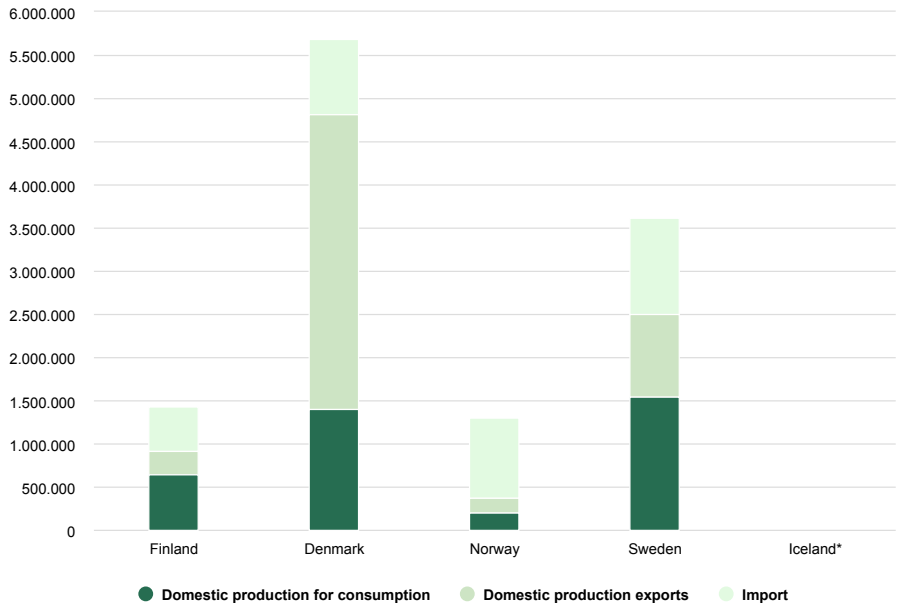


Figure 7. Domestic production, exports and import shares of wheat in total volume. *Data presented for Iceland is aggregated coffee imports, not distinguished between the Arabica and Robusta beans. Total imports represented in the Arabica diagram. Data for Iceland should be read with caution – they are the best available data, based on FAO agricultural estimates for 2020.

The main results of the study present the risk and opportunity shares for the most important trading partners for each crop for the Nordic countries, as shown in Figures 8 and 9. Since Icelandic data were not available on the detailed level of analysis provided by the index, we present the best available data for Iceland for the five crops available separately in Figure 10.

Across the Nordics, the risk profiles for the six studied commodities show a high degree of similarity in the exposure of risk in the markets, the main geography of major risk and opportunity markets, and the degree of diversity of the suppliers to the Nordics. The highest climate risk is found in the supply of maize, where the risk in the supply outweighs the opportunities by a factor of 28 (Figure 8). Maize is followed by sugarcane, for which the equivalent risk-to-opportunity ratio is 24 to 1 (Figure 9), and the coffee supply chain, where high risk is recorded across the entire production system for both the Arabica and Robusta beans. Wheat is the only commodity with an optimistic prediction for Nordic patterns of imports, with the opportunities outweighing the risks by a factor of 5 (Figure 8).

Looking at the available trade data for Iceland (Figure 10) from a risk exposure perspective, it is striking how a few trading partners make up the majority of an entire import of a certain commodity. This leaves Iceland in a very vulnerable position, should one or several of those supplies be jeopardised. Another key insight drawn from the Icelandic data is just how inadequate global trade statistics can be in depicting the origin of produce. For example, 95% of the Icelandic imports of soy come from the Netherlands, Germany and Denmark, according to available data. This most likely reflects the latest port of entries for shipment of soy from Brazil, the United States or Argentina.

In comparison to global risk levels in these markets, the overall climate risk ratio for

the Nordic countries is lower than the global ratios. This is the case with all studied commodities, with the exception of coffee, where the opportunities are diminutive in both the global and Nordic assessments. A comparison between Nordic and global risk ratios is provided in Table 7 in the next section.

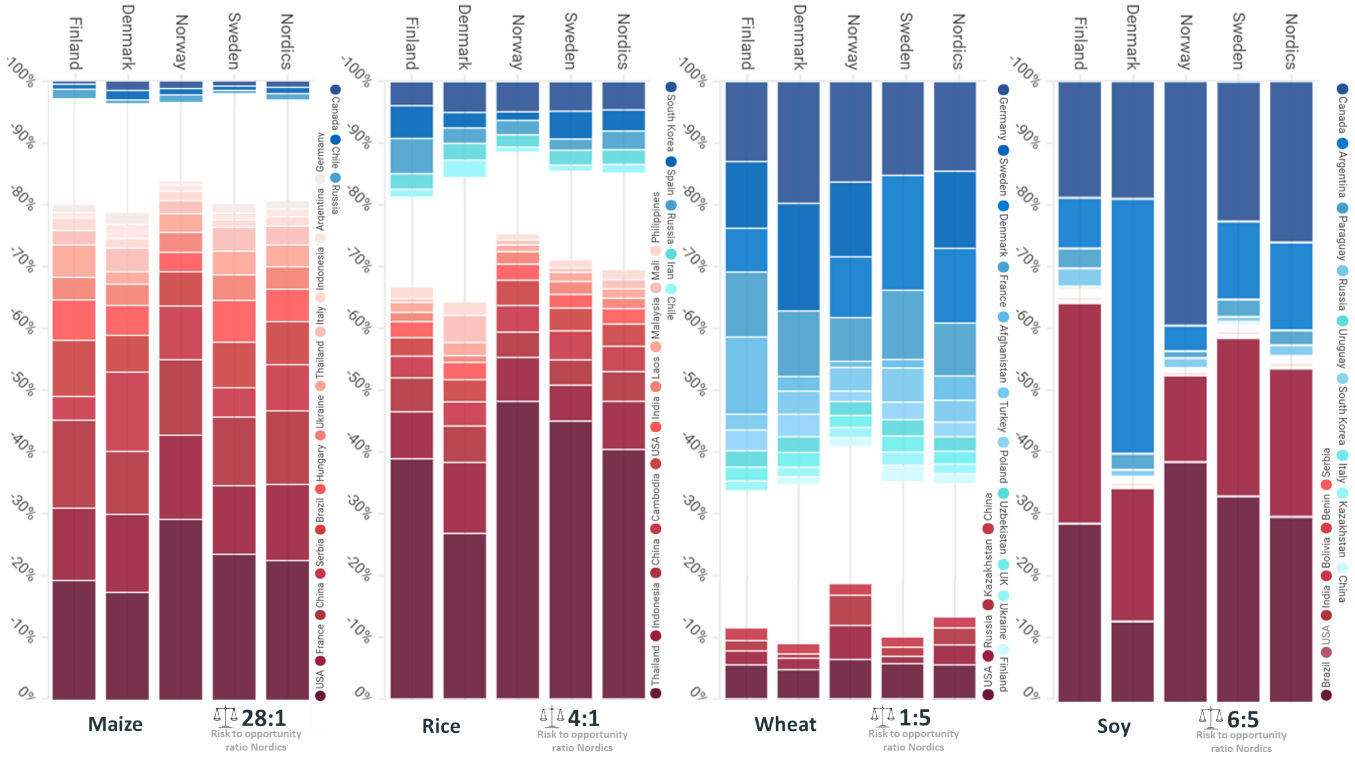


Figure 8. Risk and opportunity values for maize, rice, wheat and soy in the top 15 trading partners based on risk-opportunity ratings. Red bars show risk relations, and the blue bars depict opportunity markets. Note that the bars do not represent physical flows – but risk to opportunity shares, based on current market shares, predicted changes in yields and the concentration of supply.

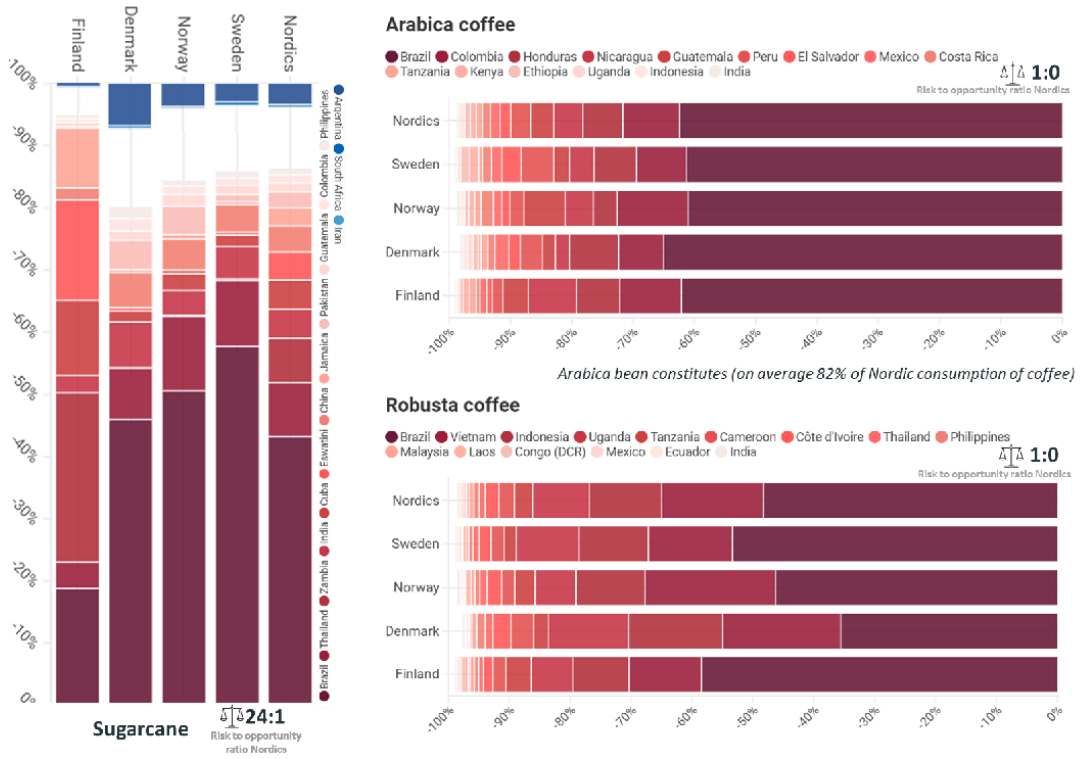
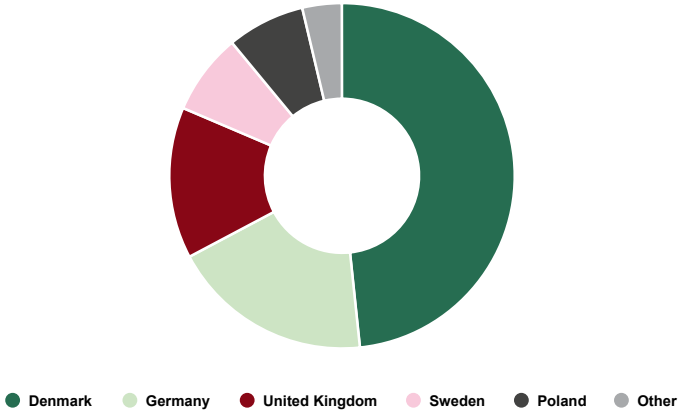
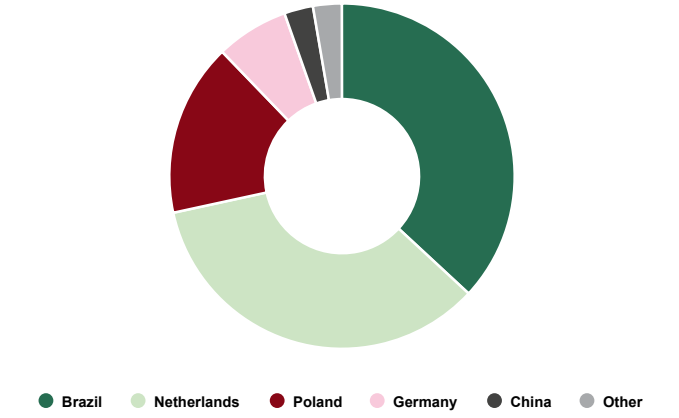


Figure 9. Risk and opportunity values for sugarcane and the two coffee beans Arabica and Robusta in the top 15 trading partners based on risk-opportunity ratings. Red bars show risk relations, and the blue bars depict opportunity markets. No opportunity markets have been identified in the coffee supply chain.

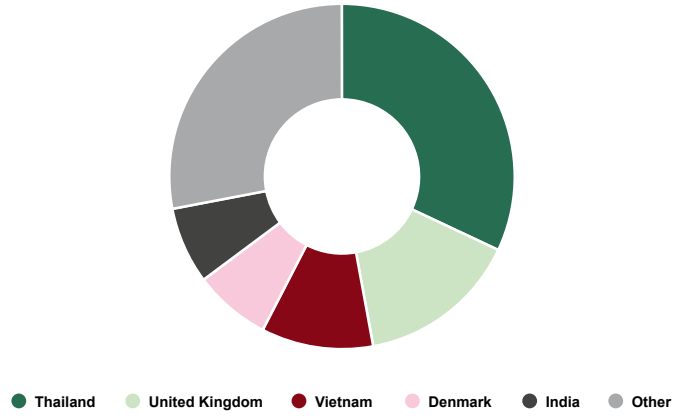
Wheat



Maize



Rice



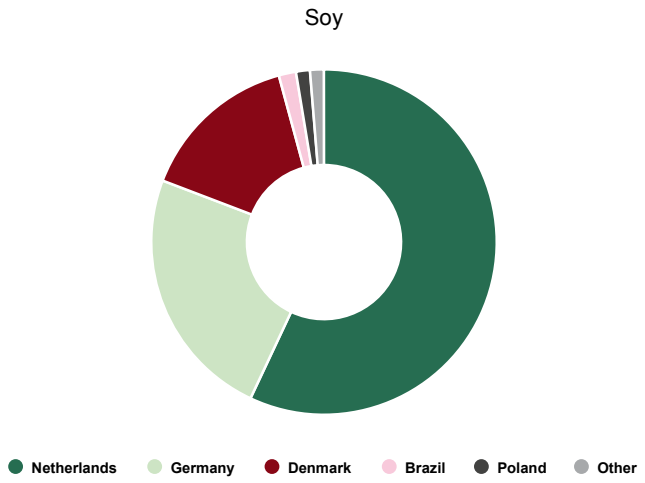


Figure 10. Agricultural import data for Iceland based on FAO data from the latest available year (2020), showing the top five import partners for Iceland and the rest aggregated in "other" (FAO, 2022). No data are available for sugarcane and coffee.

Looking closer at the results, there are also important differences to note. The section on "typology of risk" below describes the key traits of the Nordic risk exposure in the light of these similarities and differences.

5.2 Key types of transboundary risks in Nordic food trade

Five key themes emerge from the results and provide the basis for a typology of risk of the food trade system for the Nordics. The typology ultimately helps to inform the different types of responses that might be suitable to address the risk. The dimensions of risks emerging from this analysis are: (a) overall level of risk in a system (low-high), (b) diversity of supply (low-high), (c) geography (distance to importer, geographical spread of inputs), (d) ratio of domestic production to import reliance and (e) the commodity's level of embeddedness. Based on these five categories summarised in Table 7, the risk exposure for each crop is discussed below, highlighting similarities and differences for the Nordic countries.

Table 7. Overview of crop properties and climate risk for the Nordics

Factors assessed	Maize	Rice	Wheat	Soy	Sugarcane	Coffee
Climate risk	High	High	Low	Medium	High	High
Nordic risk-to-opportunity ratio	28:1	4:1	1:5	5:4	24:1	1:0
Global risk-to-opportunity ratio	43:1	6:1	1:1	2:1	25:1	1:0*
Predicted change in yield for major trading partners	decline 10–50%	decline 20–70%	increase 8–50%	from 30% decrease to 110% increase	decline 30–80%	decline 30–60%
Diversity of supply	High	Medium	Medium	Low	High	Medium
Main sourcing regions	North America, Europe and Asia	Dominated by Thailand, alternative sources centred in Asia	Dominated by the Nordics and other parts of Europe	Brazil, the US and Argentina, Canada as emerging	Dominated by Brazil, alternative sources in Asia (and Africa)	Dominated by Brazil, alternative sources in South and Central America and Africa
Domestic production	Insignificant	None	High	None	None	None
Embeddedness	Medium	Low	Low	High	High	Low

* Rounded-up values; actual global risk-opportunity ratios for coffee globally are 1,560:1 for Arabica and 336,772:1 for Robusta.

5.2.1. Maize

Typology traits: High risk – diverse sources – geographically spread – low domestic production – medium high embeddedness: inputs to agriculture

Agriculture in the Nordics has a strong focus on animal production, due to the short growing seasons and landscape types, as well as agricultural and culinary traditions. Imported maize for feed for cattle (for meat and dairy), pigs and poultry is an important input to the domestic agricultural systems. Denmark, with its large agricultural production and export, including its large pig industry, imports the largest volumes of maize of all the Nordic countries (total and per capita inputs).

The climate risk in the supply of maize for the Nordic countries is high, the risk outweighing opportunities by a factor of 28. The crop yields for the Nordics' major trading partners are projected to decline by 10–50%. The sourcing patterns for the Nordics show a diverse portfolio, and sourcing countries are spread across several continents, including North America, Europe and Asia. The largest risk share derives from the US, followed by France and China. There are a few minor opportunity markets in the maize supply chain in Canada, Chile and Russia. They are currently minor global producers and exporters of maize to the Nordics, but future yield predictions look optimistic. The only country in the Nordics with a recorded domestic production of maize is Denmark, representing 1% of total maize inputs for the country. The actual domestic production may be somewhat higher, as animal farms may have in-farm production of maize that is not recorded in national statistics. Maize should be treated as a medium-high embedded commodity for the Nordics, due to the substantial input of maize to domestic production systems. Nordic

citizens also consume maize in embedded form, such as in Polish milk that is an ingredient of a chocolate bar processed in Switzerland, to give one example.

The high diversity of sourcing patterns, spread of geography, and small but emerging opportunity markets mean that although the risk is high in the maize market for the Nordics, there is a chance that the market can deal with at least some of the risk. Alternatives for action include changing suppliers – as one region might be more affected by decreased yield one year but another not – and in the long term, look towards new markets, or even increase domestic production. However, the increased demand of food, and especially animal products worldwide, could put even more pressure on future markets and drive price hikes. Diversifying might not be enough to secure Nordic supplies of maize to future farmers.

5.2.2. Rice

High risk – dominant high-risk partner, with alternative options – no domestic production (but alternative crops) – low embeddedness

Rice is not produced in the Nordic countries, and it is a fairly new addition to the Nordic diets. In the Nordics, consumption of rice is lower than for the other staple crops studied, but it has grown exponentially over the past few decades.

The climate risk in the supply of rice for the Nordic countries is medium high, the risk outweighing opportunities by a factor of 4. The predicted decline in yield for the major trading partners in the Nordics ranges from 20% to 70%. The sourcing patterns for the Nordics are dominated by Thailand, but with a diversity of trading partners throughout Asia, such as China, Vietnam and Indonesia. There are a few opportunity markets in the rice market, mainly represented by the predicted increase in yield in South Korea. The Nordic countries have no domestic production of rice, although the consumption of rice could be substituted by domestic grains based on wheat (wheat corn, bulgur, etc.). Rice is used as a staple in its own right and has low embeddedness.

The high risk, dominant but existing diversity of suppliers for the Nordics, and the possibility of substituting rice for other types of grains in the Nordic consumption suggest that a shortage of rice on global markets could be handled by first changing suppliers, and second, switching to other foods, if available.

5.2.3. Wheat

Low risk – high diversity – geography dominated by the Nordics, Europe and central Asia – high domestic production – low embeddedness

Wheat constitutes a staple in the Nordic diets, consumed in bread, cereal, porridge and pasta. However, the consumption of wheat is growing in complexity for the Nordic countries, from a high consumption of wheat in its refined form to an increased consumption of processed wheat in ready-baked breads and pasta, to give a few examples.

The risk in the wheat market for the Nordics is relatively low, opportunities

outweighing risks by a factor of 5. There is a high diversity of supplies of wheat in Nordic imports. The geography of imports is dominated by production in the Nordic countries themselves and by European neighbours such as Germany and France, followed by countries in Central Asia and Russia. Iceland sources the bulk of its wheat from Denmark. There is a substantial domestic production of wheat in the Nordic countries. Denmark produces the majority of its wheat for exports, followed by Sweden, which matches the domestic production with its overall consumption rates. As discussed above, wheat has a low-to-medium but increasing embeddedness related to the complexity of the global food systems and supplies. The outlook for domestic Nordic production of wheat is optimistic, with predictions of increased yields between 8% in Norway to 50% in Sweden.

The climate risk related to wheat is relatively low, considering the production of wheat in the Nordics and the sourcing geography centred on Europe. The analysis even suggests a potential increase of domestic production of wheat for the Nordics, which could lead to increased exports. In case of global shortage of wheat supplies, there is a good chance that the Nordic countries could reduce their exports and focus on domestic provision of wheat for their own use.

5.2.4. Soy

Medium risk – low diversity of sources – geographically locked (few alternatives) – no domestic production (alternative crops) – high embeddedness

Soy is rich in protein and oils, and a major source of animal feed protein globally. As such, similarly to maize, the majority of soy imports for Nordic consumption are found within the animal production systems, for cattle (meat and dairy), pigs and poultry. Soy is also used as fish feed in the large aquaculture industries especially in Norway, Finland, Denmark and Iceland.

Climate risk in the soy market for the Nordics is medium-high, with a near-equal opportunity-to-risk ratio. The market is dominated by a few actors, with Brazil and the US presenting the largest risk markets, and Argentina and Canada providing future potential opportunity markets.

Denmark diverges from its Nordic neighbours, with a higher opportunity than risk, based on current sourcing patterns, due to its larger share of soy inputs from Argentina. Denmark is also the largest importer of soy by volume of all the Nordic countries, largely related to its large animal production system.

Although risk-to-opportunity ratios are even in the soy market, it is important to note that the opportunity markets for soy should be read with extra caution. The high opportunity in the Canadian market is based on predicted yield increases of 117%, and the volume of soy produced in Canada is currently low. The yield prediction models for soy are also known for an optimistic interpretation of the potential for increased yields due to the increased atmospheric CO_2 fertilisation.

There is no domestic production of soy in the Nordics. However, there are possibilities of substituting soy with other high protein-crops that can be grown domestically. Soy is a highly embedded commodity in food products as diverse as an American candy bars, Polish sausages, or meat and dairy in a ready-made lasagne, with multiple origins of input components.

Response options for the Nordics to climate risk in the supply chain for soy again look different from the other crops discussed. For the direct use of soy in Nordic agricultural systems, the risk analysis points to a future opportunity to perhaps be able to switch suppliers from Brazil to Argentina or Canada if those production systems are less affected, at least in theory. Being the number one global protein for animal feed and a highly embedded commodity, however, a shortage of soy in the global markets is likely to result in global shortages and price hikes across a number of commodities. As a result, we might see a bidding frenzy and difficulty to secure supplies in the future market. The prospect of substituting soy with other high-protein crops is tempting, but the volume of inputs needed are substantial, and it is not clear whether domestic or even European production can bear the load.

5.2.5. Sugarcane

High risk – dominant high-risk partner, with alternative options – several geographical core regions – no domestic production (but alternative crops) – high embeddedness

The embedded consumption of imported sugarcane is among the highest by volume for the Nordic countries. The climate risk in the supply of sugarcane for the Nordic countries is high, with risks outweighing opportunities by a factor of 24. The predicted changes in yield for the major trading partners in the Nordics are at a 30–80 percentage decline. The sourcing patterns for the Nordics are dominated by inputs from Brazil, but with a diversity of smaller trading partners in Asia, such as Thailand and China. Interestingly, Finland stands out in its sourcing patterns, with the highest total import of sugarcane across all the Nordic countries. Finland also has a different geographical sourcing pattern, focused predominantly on inputs from African countries, including Eswatini and Zambia, as well as Brazil and Caribbean islands. While the Nordics have no domestic production of sugarcane, they produce sugar beet (especially Denmark and Sweden), which is not accounted for in this data. Sugarcane is a highly embedded commodity, included in complex food production systems globally.

With a high-risk, high-embeddedness profile, it is likely that climate impacts in the sugarcane supply chain will predominantly result in price increases across a basket of products. Although the domestic production of sugar beet could, in theory, replace the consumption of imported sugar, the complexity of the system it is embedded in might make such a shift difficult as a strategy to avoid the risk in the sugarcane supply chain for the Nordics.

5.2.6. Coffee

High risk – dominant high-risk partner, with alternative options – three dominant geographical regions – no domestic production (no alternatives) – low embeddedness

Coffee is different from the other crops studied here, as it is a luxury good. However, coffee is culturally important for the Nordic countries; they are among the biggest coffee consumers in the world on a per capita basis. More than 80% of all coffee

consumed across the Nordics is of the Arabica bean, a higher quality bean predominantly grown in South and Central America.

The climate risk in the coffee supply chain is the highest of all crops studied in this analysis. All current significant production systems in the coffee market for the Nordics report predicted declines in yield, for both the Arabica and the Robusta bean. The predicted decline in yield for the major trading partners in the Nordics varies between 20 and 60%. The Nordic sourcing patterns for the Arabica bean, the preferred high-quality bean, are dominated by inputs from Brazil, but with a diversity of smaller trading partners in South and Central America, such as Colombia and Honduras, and East African countries, such as Tanzania and Kenya. For the Robusta bean, the geography is slightly different, with the highest risk shares, aside from Brazil, deriving from Asian countries, such as Vietnam and Indonesia, and a slightly different set of African countries, such as Uganda and Tanzania. Because of its specific growing conditions (altitude, climate etc.), domestic cultivation of coffee in the Nordics is not possible.

The coffee supply chain outlook is plain when it comes to response mechanisms for the Nordics. If we want to keep drinking our morning coffee, there are no low-risk alternative markets to turn to. Even if we alter bean preferences and start drinking the Robusta bean, mostly used for the production of instant coffee, the risks in the supply chain remain high. The only real adaptation option left from a Nordic perspective, is to support adaptation efforts in the producing areas, increasing the chances that the predominantly small-scale coffee farmers can adapt to a changing climate.

5.3 Interview results – adapting to a changing climate in the food and agricultural sector in the Nordics

This section provides an overview of the key results of the food and agricultural sector interviews. The interviews have been spread across both the agricultural and food sector, and include all five Nordic countries, but the analysis does not claim to be exhaustive. It does, however, provide a first glimpse at the dynamics and core issues for the food and agricultural sector for the Nordics, when faced with adapting to a globally changing climate.

5.3.1. The Nordic capacity to adapt

Based on history, landscapes and climate, politics and value systems, the Nordic countries all have their own different approach to **food security**, and how it is perceived and approached in a national context.

For **Denmark**, with a large export-oriented agricultural production and food industry and a small population, food security "is nothing we really talk about". The food industries and agricultural sector, however, rely on foreign inputs such as fuel and feed, and stakeholders shared experiences of recent price rises in imports. The agricultural production and food industries are largely regulated by market mechanisms and EU regulations.

The outlook is different in **Finland**, with geopolitical tension due to its long border with Russia and a living memory of wars, occupation and food shortage. The country has held an active policy and practice of domestic food production, supply and storage, as part of the contingency plan in event of crises. Although maintaining a strong emphasis on food security and pride taken in Finnish-produced foods, the stakeholders interviewed suggested that in reality the security of supply has weakened significantly over the past decades. This is due to increasing input dependency in the domestic agricultural system, an increased demand of out-of-season products (such as fresh vegetables in the winter), and the increasing complexity of consumed food products: "Food security is no longer secured, even in Finland."

In **Sweden**, the end of the Cold War and the entry into the EU were followed by agricultural reform and a shift to lean production and supply in the agricultural and food systems. As a result, the sectors were industrialised and conglomerated, shifting agricultural production to fewer products and fewer but larger farms. Today, more than half of the food consumed in Sweden is imported directly, and there are no active reserves or storage facilities. There has been no active policy aimed at food security in Sweden for decades; the debate just recently picked up again.

Norway has a somewhat different approach in its agricultural and food industry. Norwegian agricultural policy's main task is not food production *per se*, but keeping possibilities for livelihoods across the country. This includes making sure agriculture can still be carried out on steep mountainsides and in remote and climatically harsh areas from the north to the south. According to several Norwegian stakeholders, keeping all of Norway inhabitable and alive is a key reason why Norway has not joined the EU. Still, achieving a higher level of self-sufficiency in food is a key goal for Norwegian agriculture policy.

Iceland, as a small, isolated island in the North Atlantic, is a story just by itself. With large fisheries but only very limited domestic production of other foods, such as cattle, sheep and dairy products, potatoes, and greenhouse production of cucumbers and tomatoes, Iceland is dependent on imports for most of its consumed food. Despite its high vulnerability due to high dependence on a handful of key import partners, and the recent experience of supply shortages during the financial collapse in 2008, food security has not been high on the agenda, although that is changing.

Across the Nordic countries, the **past years' crises have increased the understanding and sense of urgency** in relation to climate risk in the food and agricultural systems. Repeatedly, the sectors have suffered shocks of different kinds, from the last years' droughts and floods within and outside of the Nordic countries. Examples are the forest fires and droughts in Northern Europe in 2018, which forced cattle farmers in Sweden to mass-slaughter their animals for lack of fodder and a shortage of fodder on import markets. For Iceland, the financial collapse in 2008 was also a significant event in understanding how vulnerable and how reliant on foreign inputs the country is. The COVID-19 pandemic has added kindle to those embers, causing shortages of supplies of everything from grains to packaging, as well as insecure deliveries. The experience of recurring disruptions, even if not caused by climate-related events or a virus, have been eye-opening events in the Nordic setting.

As one stakeholder put it: "I think the pandemic has opened the eyes of the people – that the climate change impacts can have exactly the same effects." Another one

reflected on food supplies: "Climate change is well recognized now. We can really feel and see it. Before we had normal years; now there are no normal years anymore – there is too much variation." Despite the growing awareness of climate impacts, and cross-border and cascading climate risk, the notion is still fairly new. Private sector actors call for increased knowledge on how these risks might affect consumption and production systems with a time frame of 5–10 years. Current predictions focus on effects in the coming decades, often with time frames from 2030 (at best) to 2100.

Experiences from the COVID crisis from an industry perspective are mainly related to price pressure, shortage of supplies and increased delivery times leading to spoilage of certain commodities. Issues with transport and access to packaging (due to a shortage of cardboard) were also repeatedly mentioned as effects of the pandemic, leading to increased prices, delays, spoilage, and lower quality of products. Similar effects are expected as a result of the changing climate and an increased pressure of global production systems. This, in turn, has an effect on food supplies.

Examples mentioned by stakeholders include delays in shipments of dried fruits for muesli that were spoiled or past the expiration date when finally delivered. Another example is the experience of suppliers of wheat. Weather events in the past years have repeatedly affected the quality of wheat, producing exceptionally high protein levels. High protein levels make it hard for bread to properly rise, and as a result make it increasingly difficult for bakeries to produce bread in industrialised facilities. For home baking, this proves less of an issue: "With the change in quality of wheat, either we have to go back to baking all of our bread at home, or the consumers have to get used to that bread is simply flatter in the future."

Food industries and retailers in the Nordics report an increased pressure, being left **hard-pressed to bargain**. Shortages on the markets have made companies that normally have a good relationship and control over their sourcing partners "forced onto the spot-market". Actors are being pressed to source from unknown suppliers, resulting in less overview and control of the supply chain, including of whether sustainability and social standards are upheld. "Although a lot of focus is put on codes of conduct and quality etc., in the end, the economy decides." This is the case also for retailers and industries that prefer to build long-term relationships with producers and suppliers. One example mentioned is the move from wheat produced far away, such as an Australian supplier being taken off the Norwegian market because of high emissions from shipping.

This is not only the case for upholding environmental and social standards of production abroad, but also related to the quality of imported goods. If, for example, cereal or feed inputs are in short supply globally, the Nordics might have to lower their input requirements, which might change the requirements Nordic consumers can put on the products. An example brought forward by a stakeholder: "The reason why we don't buy US produced soy much – especially in Norway – is because the content of genetically modified soy and specific allergens in US-produced soy is so high. With climate change we might not have so much choice but to lower our standards and import from wherever we can."

The overall food industry experience is that they are short on actionable options and time. Stakeholders said they have "empty toolboxes". Another stakeholder reflected that they are "acting on volley". The stakeholders reported highly reactive responses

to these market dynamics: "We just see what happens and try to manage as well as possible. The [risk] awareness is there but not so much we can do besides from acting fast on the market."

Food industries and retailers are not the only ones squeezed on the market. **A plethora of interacting risks in the food and agricultural sector add pressure to farmers and food industries alike.** Price increases and shortage of supplies are reported as the main immediate effects of scarce feed and input supplies across the Nordics, further straining the hard-pressed farmers' production systems, with already tight margins. Climate risks in food systems for the Nordic countries are often perceived first and foremost in light of climate mitigation and risks related to the transition to climate-neutral practices, affecting production, transport, processing and storage systems. Increased environmental and animal welfare standards, EU food safety regulations, and increased animal feed and fuel prices cause difficulties for farms to stay profitable. Low profitability and resources, in turn, inhibit investment in adaptation.

This results in small and medium-sized farmers abandoning their trade, with a loss of diversity of actors and some farmland bought up by larger producers. This has led to fertile lands being left fallow. Overall, the added pressure to already strained production systems is reported by stakeholders in Denmark and Sweden to have resulted in a decrease in the overall farmed area. As expressed by one stakeholder: "With all of the pressure on future farming, there is no place for evolution and adaptation, but instead the smaller farm simply has no option but to shut down. The transition is difficult, and takes time." In Denmark, the past few years of more irregular weather events affecting the agricultural systems have led to an increased discussion of risk in the sector, with farmers' cooperatives starting to talk about risk and prevention, and a booming market for private insurance.

In the agriculture and food sectors alike, stakeholders describe that there are **very few preventive actions** to take: "Every year the cards are dealt – and then we deal with it." One risk management option described by stakeholders is an active diversification of sources to ensure a secure supply should one sourcing partner fall short. Upholding a diversity of import partners would come at the expense of increased prices and lower quality. Active contingency politics and solutions are brought forward as solutions in the face of crisis, including an increased domestic production of food and agricultural inputs (as well as fertilisers and fuel). In Iceland, a shift to a completely electrified production system is mentioned, and reactivating fertiliser production in Sweden is another example. The lack of storage facilities presents another infrastructural barrier. There are ongoing attempts to decrease dependence of crucial inputs to agriculture, specifically aimed at the substitution of soy, largely related to the awareness of deforestation risk in the soy production system. Potential substitutes for soy better adapted to Nordic climatic conditions are being explored, including the use of rapeseed, peas and grass proteins and insects (insects primarily for fish feed). The potential for an increased self-sufficiency is limited in the Nordic climate and landscapes, however, and because of the embeddedness of the global food systems: "Even if it gets warmer so crops grow better, and we get to keep our good water reserves, we can't change the amount of sun hours in the winter – the growing season can only be that long."

The effects will also be felt by consumers, and may result **in altered consumption patterns.** For the duration of the pandemic, the sector has so far taken the brunt of

the costs. But the increased costs are now starting to be pushed over to the consumers**.** There are differences between the Nordic countries in how this is handled. In Sweden, for example, the price effects are felt by the consumers faster, and follow the global market prices, which makes it possible for the retailers to sustain a high availability of food to higher prices: "So at least there's always something to eat – if you can't afford imported tomatoes, you can always buy cabbage." In Norway, meanwhile, due to high import tolls, it takes longer before prices on the global markets affect Norwegian customers directly.

The experience of past years' crises has also led to autonomous changes in consumer behaviour, driven by consumer preferences. In Iceland, the financial collapse is reported to have driven a surge in demand for more traditional Icelandic food and less complex commodities: "All of a sudden all of the food stores had to sell ingredients to this traditional dish – like an Icelandic Haggis." Several stakeholders point out that some behaviours however are easier to shift than others: "Take for example breakfast cereal – if there's no chocolate, ok, then we change to another flavour, like strawberries. But we can't stop eating bread." Another example cited was the possibility of shifting the growing consumption of rice in the Nordics to domestically produced grains and wheat-based products such as wheat kernels or bulgur. A rising awareness of climate change and environmental issues is also driving an increase in demand for more plant-based diets, both from the consumer side, and as a deliberate effort from retailers to minimise their carbon footprints. Such a shift could to some extent enable higher potential for self-sufficiency in production for the Nordics.

5.3.2. The Nordics in the global context

The Nordic countries are small open economies, and rely on direct imports and inputs from foreign markets for their agricultural production and food supplies. They are also **small actors on the world markets.** Several retailers and food industry stakeholders reported not having enough bargaining power due to their size, and thus sometimes being left without. This was the case for Norwegian cereal imports during the pandemic: "It has been difficult to get what we need – we really noticed how small a buyer we really are. It is hard to compete on the market." In Iceland, "during the financial collapse, and the high inflation rates, we couldn't compete on the market – shipments would pass us, but not stop here". Even when Nordic buyers still have money left to spend, selling to such small markets might not be worthwhile for global market actors.

Global geopolitics notably affects the market dynamics. Stakeholders mentioned the potential effects of China's situation and actions as a point of concern. China is such a large producer and buyer on the market that its production rates directly affect the global and Nordic markets. For example, the past years' increased production of Chinese pork had an effect on the Danish export markets of pork. China's increased demand for cereal stresses the whole market – and is seen as a large risk, especially for Norway that imports most of its consumed wheat. There is also a risk that China's own production of food declines because of climate change, moving China to buy more on the global market, and leaving the rest of the world hard pressed to source supplies.

The **potential for Nordic deliberate action on the global markets** was mentioned often by stakeholders as an opportunity. Across the Nordic countries, there is a strong tradition of private-public partnership, active value-driven international politics with a strong focus on raising environmental and social standards, and a strong international presence through development cooperation. Several stakeholders mentioned the possibility of exporting or sharing "the Nordic way" – the term incorporating a broad spectrum of typical Nordic global interventions, from the world's strictest animal welfare regulations to private-public partnership in development cooperation.

Initiatives from a private-sector perspective are currently largely aimed at philanthropic activities. The sectors are not yet targeting adaptation support to their own producers, or even producer regions. One example is a Scandinavian coffee roaster engaged in a capacity-building initiative to enable climate adaptation targeting small-scale coffee farmers in East Africa. The roaster sources no coffee from that region, however, but mainly from Brazil and Central America. This is despite a reportedly close relationship with producer organisations. In Denmark, a public-private partnership aims at improved and climate-adapted agriculture in Nigeria. However, the partnership focuses on the add-on intention of creating foreign markets for Danish food technology and innovation, rather than on Danish food imports.

5.3.3. Potential for Nordic collaboration

The Nordic region is known for its **high awareness of social and environmental impacts of supply chains**. For example, the high public awareness of deforestation risk related to the embedded consumption of soy has led to extensive use of certified soy across the Nordics. This approach stands out in a European and global context. It reflects the strength of flexibility in the relatively small and culturally similar Nordic region. In Norway, a specific law is in place banning the import (including transport through the country) of genetically modified soy. It also affects the Swedish supplies of soy as 60% of Swedish soy imports passes through Norwegian harbours. As much soy from the US-market is genetically modified, the Norwegian and Swedish actors have relatively few options, environmental standards withheld. Sustainable palm oil is another commodity that has been much in the spotlight for Nordic food industries and retailers in relation to environmental and social standards.

A traditionally strong labour rights movement in the Nordics and a dominant social-democratic value system also put social issues such as labour rights, gender issues and international solidarity high on the agenda for Nordic consumers and food industry. This also drives on-the-ground-collaboration and supply chain transparency. Engaging deliberately in the global market production systems and climate resilience could make it possible to "export" good practices to other regions.

Stakeholders see high potential in Nordic collaboration based on the similarities across the Nordic countries in the food and agricultural systems, related to **culture, traditions and value systems.** The Nordic countries share a strong focus on animal production (cattle, poultry, pigs, aquaculture), which provides opportunities for collaboration in the sourcing of inputs. Another common feature is organisational: a

strong presence of farmers' associations actively engaging in Nordic collaboration, as well as similar retailer groups and food industry actors, with a strong presence of cooperatives. There is existing private-sector collaboration for retailers and the food industry both in a Nordic and European setting. It is also fairly common that food retailers and industry have common ownership across several Nordic countries (e.g. Coop, Lantmännen, etc.) or deep collaboration (e.g. in sourcing supplies from abroad). The ease for the Nordic actors to understand and talk to each other, together with the tradition of primarily cooperating on markets, rather than competing, could facilitate collaboration.

Another aspect of the "Nordic way" discussed by the stakeholders is the strong tradition of, and potential for, **supporting innovation, technological advances, management of production systems and a whole-of-system understanding** and providing knowledge. "We have a lot to offer the rest of the world in relation to climate issues."

Nordic collaboration within the EU is another important avenue of policy impact, especially related to raising environmental issues, food safety regulations and animal welfare standards, where collaboration is already in practice. The **fisheries sector** also carries many similarities across the Nordics and is an important economic sector. The sector will face similar challenges in a changing climate for the region, and thus is lifted repeatedly as offering much potential for future collaboration.

Lastly, stakeholders emphasised the potential in Nordic collaboration of adaptation **research, management and knowledge sharing**. Specific examples raised are research on drought-resistant crops for the Nordic climate, centralised Nordic risk prediction institutes, sharing risk management practices as well as preventive action and market response mechanisms. The strength of employing an open mindset was pointed out, focusing on adaptive systems, flexibility and a willingness to innovate. Being humble in the face of the unfolding crisis can also help: "knowing that we don't know how the future will play out". Finally, the need for collaboration across sectors and institutions was emphasised. The efforts should be incorporated into already existing structures.

6. Conclusions

This study reveals the importance and complexity of considering transboundary climate risks. Both the scientific literature review and the empirical work conducted during this project reveal that we are just starting to understand and identify the risks. The issue has still not been fully explored in adaptation research, and it is only beginning to be addressed in Nordic policies – and far more in some countries and sectors than in others.

The COVID-19 pandemic and the war in Ukraine have provided stark reminders of the vulnerability of supply chains and economies in a closely interconnected world. At the same time, the latest IPCC report warns that climate risks are becoming more complex and intertwined with other societal risks (IPCC, 2022). In that context, this section distils insights from this project about how Nordic policy-makers and businesses are addressing transboundary climate risks today, the challenges ahead, and the potential for Nordic action to deepen knowledge of these risks and address them collaboratively.

6.1 Current awareness and action on transboundary climate risks

The analysis shows that the Nordic region is ahead of most in addressing transboundary climate risks, but preparedness varies across countries. Approaches to adaptation policy differ as well, affecting how transboundary risks are addressed – but, in general, this is still among the least prioritised topics in Nordic countries' adaptation policies.

In Sweden and Finland, there is growing attention to transboundary climate risks, and various sectors have been reviewed for their vulnerability, Finland has also paid a lot of attention to security of supply. In both countries, the debates have been primarily framed as relevant to national-level governance, while in Norway, some of the emerging debate has also made connections to regional and local governance. Iceland's first national climate adaptation strategy, adopted last year, mentions some transboundary issues, but focuses mainly on domestic risks. In Denmark, transboundary risks appear to only have been addressed in a report commissioned by an NGO.

In all the Nordics, trade – especially the import of agricultural commodities – is one of the main sources of concern. Even though the Nordics mostly trade with other countries that are fairly climate-resilient, several important commodities, such as soy, coffee, cocoa and fruit, come mostly from more vulnerable developing countries. The import of soy from Brazil for animal feed is particularly exposed to climate risks. Overall, the concern for the Nordics is that food costs could rise, and supplies of important commodities could be limited.

The risk regarding import and export of energy in the Nordic countries is linked to climate change affecting infrastructure, such as the power grid, oil and gas pipelines, harbours and roads. In this context, an important gap in existing knowledge and policy responses is that they focus on risks to today's infrastructure, but the energy sector is changing rapidly to shift away from fossil fuels. Transition risks and risks to

future energy systems still need attention. The same is true of transport systems, which also face transition risks and risks related to global transport corridors, for example.

In general, knowledge about transboundary risks varies across countries. Risks related to several transmission pathways and sectors have been identified, but there is little to no information on how to deal with those risks. More work is needed to determine what kinds of measures should be taken and who should be responsible for doing so (risk ownership). The documents also tend to use conditional terms – may, could, perhaps, possible – and passive language, and they do not mention concrete time horizons, just terms like "in the future".

Interviews suggest that although Nordic countries' approaches to transboundary climate risks have varied, the actions needed are similar. There is a common understanding on the need for awareness-raising among policy-makers, and for public dialogue between the governments, companies and the civil society. There is also a shared need for more information and analysis on the risks, their magnitude and their costs on each sector, as well as on potential cross-sectoral impacts.

Supply-chain risks clearly need attention, especially as the COVID-19 pandemic showed that countries are not well prepared for supply-chain disruptions. Actions are needed to improve resilience. Two key strategies are to find alternative suppliers, and to support resilience-building in the countries directly experiencing climate impacts. Businesses are key actors here, and any policies should consider how to enable businesses to improve their preparedness. The largest businesses in sectors such as manufacturing or food industry are already addressing transboundary climate risk, but there is a need for more systematic work on identifying and addressing supply-chain risks.

6.2 Future challenges and action needs in the food and agriculture sector

The results of the sector analysis show that the Nordics are exposed to transboundary climate risks both through inputs to Nordic agricultural systems (maize and soy), and through food industries and consumption (rice, sugarcane and coffee). Highly embedded commodities (such as soy and sugarcane) pose an indirect risk to food security, as supply disruptions could drive up prices and affect the availability of a range of food products. Overall, the Nordic trade portfolios are diverse, with multiple options for alternative supplies, especially for maize. For most of the studied crops – particularly soy, but also coffee, rice and sugarcane – the risks and opportunities are concentrated in one or a few specific countries. For wheat, meanwhile, the outlook is positive, as the Nordics already produce a large share of their own supplies, and there are alternative sources in other European countries. Overall, the Nordic countries share similar importing partners for all six crops studied, providing opportunities for Nordic collaboration on the market.

The stakeholder interviews shed light on supply chains in this sector and options for action, informed by recent experiences with the pandemic and several economic and weather-related disruptions. Two main conclusions can be drawn:

The risk involves more than a price increase: Beyond what the quantitative data models show lies the question of what climate change might mean for Nordic agricultural and food systems in practice. The assumption is often that global food markets will self-regulate, and the Nordics will be able to pay more for commodities if prices increase. It is also assumed that the Nordics can shift to an alternative source or increase domestic production as needed. The interviews tell a different story, however. Past and current crises bring forth examples of cultural, psychological, business and managerial challenges brought on by price increases or supply shortages. They also raise questions about Nordic actors' future ability to actively engage in sustainability management in general.

Shifting sources or paying higher prices might not always be an option: Substitution and diversification will be increasingly ineffective in a world that faces multiple accelerating climate impacts. There is a high potential for increasingly tense geopolitical dynamics, as countries – particularly large agricultural producers – reckon with their own climate vulnerability and strive to maintain their current market shares. This is exacerbated by international conflicts such as the Russia's war on Ukraine. Both are, for example, major wheat producers to the global markets, and the war is expected to affect global wheat supplies (see, e.g., Lawder, 2022). Responses that only account for national self-interest could undermine global resilience and exacerbate the global adaptation challenge.

Future food security – and environmental and social safeguards to global and Nordic agricultural systems – is a political and a cross-cutting problem. Climate risks in food systems are managed through decisions related far beyond the current realms of adaptation measures, including through macro-economic policy, food policy, international (geo)politics, climate and environmental policy, and Nordic coordination. The way the Nordics can and choose to act will determine the region's future food security. The sector analysis indicates two possible pathways of action:

The first option is to **stay the course**: largely adopting a laissez-faire approach to managing food security in the Nordics and letting the market regulate the outcomes. Some of the trade-offs to such an approach are discussed above. There are also justice implications within the Nordic countries themselves. As the income gap increases, do we want the market to decide how wealthy someone has to be to be able to drink coffee? There is also a global justice perspective, as the Nordics can afford to pay more for rice, for example, than Senegal; that could put the burden of future global food shortages mainly on poorer countries. Increased pressures on the food industry and agriculture would also limit the space for environmental and social management, potentially contributing to further future risks. A self-regulating market approach relies on systemic resilience in the food systems making substitution and market adjustments possible – and with the predicted impacts of climate change on the worlds' agricultural systems, such resilience cannot be taken for granted.

The second option is to make a **deliberate effort to increase systemic resilience**. Such an approach would require coordination across sectors and governance institutions. It would ideally combine efforts to strengthen production systems abroad and build resilience in global markets together with measures to increase the domestic supply of inputs. The Nordic countries could actively engage in long-term adaptation support of vulnerable agricultural systems abroad, contributing to global resilience. Such an approach could in principle be designed jointly or pursued through Nordic

cooperation, but would face challenges in connection to the EU common agriculture policy and EU internal market regulations. Together, the Nordics could tackle specific obstacles, such as their limited bargaining power in global markets; engage in international politics and policy; and share insights and progress.

The choice has a time dimension. "Laissez-faire" might well work for now – until a major global crisis occurs. With multiple climate impacts straining agricultural systems around the world, market solutions might no longer be sufficient to address supply disruptions. The effects of global climate change are already being felt in Nordic food and agricultural systems.

6.3 Potential for Nordic action

Nordic countries have **well-known similarities**, such as open economies, high levels of climate awareness, and a commitment to international engagement. These provide a solid foundation for joint action. However, some shared features can also constitute blind spots, such as the heavy and – at least until recently relatively unchallenged – reliance on long, complex and vulnerable value chains.

There are also important **differences across countries**. Denmark, Finland and Sweden are EU Member States; Iceland and Norway are not. The countries also have different food systems and different approaches to adaptation, transboundary risks, and contingency planning. The COVID-19 pandemic has laid bare surprisingly stark differences in the countries' crisis preparedness and responses, and revealed an inability or unwillingness to coordinate responses between neighbouring countries.

There is so far **no coordinated Nordic effort on adaptation**. This may be partly due to the fact that the five Nordic countries are at quite different phases in their adaptation journey. Policy mechanisms and institutional arrangements also vary from one country to another.

Nordic action on addressing transboundary climate risks can build on the similarities, focusing on areas where cooperation would provide the greatest added value. An example could be **joint research projects and shared risk analysis**. As the Nordics face mostly the same transboundary climate risks, pooling resources and knowledge could avoid overlap and facilitate learning. Sectors and issues to cover jointly could include international trade, food and energy, among others.

Another promising area for joint action could be **raising awareness** about transboundary climate risks among decision-makers and in the wider public. Companies and other practitioners would benefit from concrete examples of risks and measures to address them. Policy-makers could use information on best practices for incorporating transboundary risks into adaptation strategies and policies. Going further, Nordics could also work together to evaluate the effectiveness of different measures.

Some Nordic countries and institutions have already developed interesting **tools to help prepare for transboundary climate risks**. Rather than duplicating work done at the national level, Nordic action could build on it, including taking existing tools and providing them for the whole Nordic community. These could be particularly important for smaller companies exposed to international value chains.

Even though there are significant differences between Nordic countries in **contingency planning**, further coordination and cooperation in this field could be explored. This could be done both by deepening existing bilateral collaboration, and by initiating a dialogue at the Nordic level. Taking cooperation to a material level (e.g. joint reserves) may be relatively far off, but joint rehearsals seem like a feasible place to start.

Another focus for joint action could be in **the global arena**. The Nordics represent, by and large, advanced thinking on adaptation, international solidarity and support to multilateralism. Separately, all Nordic countries are small, but together they can have a strong international voice. Global involvement can also be considered a Nordic responsibility, recognising the privileged standing of the region. Nordic coordination would be particularly justified when one of the five countries holds a seat on the UN Security Council, as Norway currently does.

A possible asset can be that the Nordic countries are often considered relatively impartial and reliable partners. In the UN system, the Nordics have repeatedly played a bridging role, **bringing together partners from the global North and South**. In addition to working together in the international arena, the Nordics could forge alliances with strategic partners in the global South.

A natural avenue for joint action is the well-established Nordic cooperation, in particular through the **Nordic Council of Ministers** and the **Nordic Council**. Other platforms could also be explored, such as Nord Pool and Nordel on climate risks facing the electricity markets and networks. Apart from improving the knowledge base, there seems to be a need for policy dialogue and coordination.

While there is a case for cooperation at the political and administrative level, one Nordic strength can be **public-private partnerships**. Public initiatives could actively involve the private sector, such as trade associations, companies, and business-affiliated research institutions. However, this may require taking into account the specific needs and conditions of businesses, such as shorter planning timeframes and the need to translate activities into business benefits.

Much of the limited work on adaptation to transboundary climate risks has so far focused on the receiving end. There is a need to explore further how to improve **resilience at the point of origin**. Integrating transboundary climate risks into research efforts and development cooperation in the global South could be one natural fit for Nordic countries.

Finally, while the Nordic countries have different relationships to the EU, the EU is a key partner to all of them. In addition to Nordic cooperation within the region and internationally, the Nordics could advocate for **joint activities with and within the EU**. A concerted push from the Nordics could help move the EU to address transboundary climate risks better.

7. Recommendations

7.1 Recommendations for Nordic collaboration

Based on the analysis presented in this report, the project team offers the following recommendations for Nordic collaboration:

- **Establish a joint Nordic research programme:** The Nordic Council of Ministers could coordinate a research programme to provide a shared knowledge base on the key transboundary climate risks facing the region. National governments could build on the analysis by commissioning, individually or together, studies specific to their circumstances.
- **Facilitate mutual learning and sharing of adaptation best practices:** The Nordic Council of Ministers could collect and document in a report best practices in Nordic countries on addressing transboundary climate risks in adaptation policy and business activities. National governments and trade organisations could use the findings to develop their policies.
- **Raise awareness about transboundary climate risks:** Based on the research programme and on the identification of best practices, the Nordic Council of Ministers could inform decision-makers and businesses in the region about transboundary climate risks and recommended responses. To minimise costs, this could happen primarily through existing channels (e.g. ministerial meetings, the Nordic Pavilion at the COP) and with existing partners (e.g. the Nordic Council, the Nordic Investment Bank).
- **Share existing practical tools:** The Nordic Council of Ministers could explore ways to share more broadly within the region tools created in various Nordic countries to address transboundary climate risks. To share costs and secure ownership, this should be done together with key stakeholders, including national governments and trade associations.
- **Deepen cooperation in contingency planning:** The Nordic Council of Ministers and the Presidency could initiate discussions in the relevant ministerial councils about deepening Nordic coordination and cooperation in contingency planning in response to transboundary climate risks. Recognising the sensitivities and different approaches related to the issue, the process would need to have strong ownership by the national governments.
- **Coordinate Nordic initiatives in the EU and internationally:** The Nordic Council of Ministers could facilitate a dialogue between the Nordic countries to coordinate initiatives on transboundary climate risks within the European Union and internationally. Possible platforms for these initiatives could be the UNFCCC, existing international climate initiatives (e.g. the Race to Resilience) and international finance institutions (e.g. the Adaptation Fund).
- **Build alliances with partners in the global South:** Interested Nordic governments could take the lead on building alliances with countries from the global South on transboundary climate risks. The aim would be to facilitate mutual learning, raise awareness internationally and possibly identify measures e.g. under the UN climate framework.
- **Engage with the private sector:** The national governments should consistently involve businesses and trade associations in discussions and planning on

transboundary climate risks. The same applies to some extent to the Nordic Council of Ministers.

- **Integrate transboundary climate risks into development cooperation:** National governments should use existing tools and funding mechanisms for development research to cover transboundary climate risks. Addressing the risks at the point of origin could also be included in development cooperation and finance, including by partners such as the Nordic Environment Finance Corporation (NEFCO).
- **Develop a joint approach to food in the Nordics**: The Nordic Council of Ministers could build on the experience of the Nordic Food Policy Lab and continue work on developing a joint approach to food in the Nordics. The approach should be centred on strong common Nordic values and practices, including environmental and social standards, public-private partnerships, and the export of Nordic solutions globally.

7.2 Further research needs

As discussed throughout the report, significant knowledge gaps remain, both in understanding transboundary climate risks faced by the Nordic countries, and especially in identifying appropriate policy responses and business strategies to address them. Three research needs that warrant special attention are:

Analysis of the transboundary climate risks related to energy and transport: This study examines risks in the food and agriculture sector, but, as discussed in Section 4.4, risks in other priority sectors need further study as well. Energy and transport in particular should be examined further, taking into account the ongoing transitions in those sectors.

The role of local and regional authorities in addressing transboundary climate risks: The Nordic countries have addressed transboundary risks almost entirely at the national level so far. That arguably represents a departure from two commonly accepted governance principles: Jurisdictional responsibility calls for the body responsible for governing a jurisdiction in a "normal" situation to also take responsibility for governing extraordinary events and crises. Subsidiarity means that issue should be handled at the lowest possible level of governance. Should jurisdictional responsibility and subsidiarity also apply in the context of transboundary climate risks?

Risk ownership: More broadly, it is important to explore how ownership and responsibility for managing transboundary climate risks should be allocated. This is particularly important in the contexts of trade and finance, as businesses play key roles, and some are already taking steps to identify and address transboundary risks. What responses are most appropriate for managing or adapting to different kinds of risks? What policy options or instruments exist along the pathways from source to impact? Further research can shed light on these questions and offer important insights for policy-makers.

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Annexes

I. Interviewed organisations

The findings presented in Section 4.3 are based on interviews with representatives of the following organisations:

Finnish Environment Institute, Finland

National Centre for Security of Supply, Finland

Confederation of Finnish Industries, Finland

National Board of Trade, Sweden

Tillväxtanalys, Sweden

The Norwegian Environment Agency, Norway

Finance Norway, Norway

Fridtjof Nansen Institute, Norway

Confederation of Danish Industry, Denmark

Aalborg University, Denmark

Ministry for the Environment and Natural Resources, Iceland

Icelandic Meteorological Institute, Iceland

II. Interview questions

As noted in Section 2.1, the interviews were semi-structured – meaning they were guided by a common set of questions, but enough flexibility to focus on each person's areas of expertise and to dig deeper as appropriate. The guiding questions were:

Policy and governance:

- To what extent are transboundary climate risks considered in policy and governance in your country? Which types of transboundary climate risks are addressed? How are they addressed – and by whom?
- What are the key improvements needed in policy and governance to better address transboundary climate risks? Who could take the initiative for these improvements to happen and who would be responsible for implementation?
- What needs, if any, do you see for Nordic policy cooperation, and how could such cooperation be advanced?
- What lessons can be learned from the COVID pandemic and policy response to it?

Trade policy and business practices:

- To what extent are transboundary climate risks considered in trade and security

of supply policy in your country? How and by whom?
- Are transboundary climate risks considered in business practice in various sectors of the economy in your country? If so, how and by whom?
- Have transboundary climate risks for businesses been identified in general?
- Have transboundary climate risks for specific business sectors been identified?
- Are climate risks considered in sourcing of products? If so, which products and how?
- Are climate risks related to supply chains considered in business practice? If so, which supply chains and how?
- What should change either in business practice or trade and security of supply policy to take transboundary climate risks better into account? You can mention several points. Who could take the initiative for these changes to happen, and who would be responsible for implementation?
- Do you see added value in Nordic cooperation for businesses on transboundary climate risks?

Stakeholders:

- From your point of view, who are the key stakeholders in your country related to transboundary climate risks? Who should know about this study?

III. Sector interviews

The findings presented in Section 5.3 are based on interviews with representatives of the following organisations in the food and agriculture sector:

Landbrug & Fødevarer (Farmers' association), Denmark

Concito, Denmark

Landbruksdirektoratet (agricultural authority), Norway

Norgesmøllene, Norway

Lantmännen, Norway

CICERO, Norway

Loftslagsráð (climate council), Iceland

Independent journalist, Iceland

Mjólkursamsalan, Iceland

Maa- ja metsätaloustuottajain Keskusliitto MTK (The Central Union of Agricultural Producers and Forest Owners), Finland

Maa- ja metsätalousministeriö MMM (Ministry of Agriculture and Forestry), Finland

S-Group, Finland

Livsmedelsverket (food authority), Sweden

ICA-gruppen, Sweden

Axfood, Sweden

Löfbergs lila, Sweden

Interview design

These interviews, which were conducted online in January and February 2022, were also semi-structured, each lasting about 45 minutes. The interviews were held in Scandinavian languages where possible (Swedish/Norwegian/Danish), and otherwise in English (Finnish and Icelandic). The following guiding questions were used:

- [Introduction: description of project background and the theme of transboundary climate risk]
- Please describe your background and current position.
- For [org X], could you describe your current climate risk management practices in general (if there are any)?
- Do you have risk management practices specifically targeted at international or supply chain risk? If so, could you describe how you work with these issues?
- Do you see changes from year to year?
- What would you say is the "state of recognition" of transboundary climate risk in the sector?
- Is there awareness of these risks, and if so, how?
- Have recent global and international crises changed the way climate risk is viewed and handled for your sector (COVID-19, droughts in 2018, any other crises)?
- Would you say that the response practices primarily preventive or reactive?
- What would be needed to better manage these types of risk?
- Who, in your view, is, could, or should be responsible?
- Do you see any opportunities for Nordic collaboration?
- Is there anything we haven't discussed here yet that you think is important to mention?

IV. Trade data analysis: Nordic perspectives on climate risk

This document provides background, methodology and analysis of the climate-risk-in-trade data analysis for the Nordics. It is supported by the online trade data explorer/tool built for the project. The tool provides the reader with the opportunity to deep-dive into a specific country and/or sector and to engage with specific datasets that are collected for this analysis.

The tool is available at https://public.flourish.studio/story/1028351/. References to "slides" are to the respective numbered slide in the tool.

Climate risk in trade for the Nordics

The five countries of the Nordic region – Denmark, Finland, Iceland, Norway and Sweden – are all small economies, deeply embedded in the global economy and reliant on both imports and exports on the global market for our economies, livelihoods and lifestyles. Trade is a crucial component in the of basic provisions of

food and energy and the imports and exports are crucial components for a substantial part of employment across the Nordic region. As cultural, historical and geographical ties connect the nations of Northern Europe – this is also reflected in trading patterns – there are similarities in trade patterns and important trading hubs shared across the Nordic region. However, the composition of the Nordic economies, sectoral inputs and trade partners also vary across the five countries.

This data analysis explores climate risk in trade for Nordic countries and in Nordic economic sectors. It does so by focusing on three main areas of analysis:

1. trade patterns: assessing key trade partners and sectors/commodity groups for the Nordics, and exploring intra-regional trade dependencies.
2. climate risk: assessing climate vulnerability of current trading partners
3. sector exposure: assessing identifying sectors-level climate risk components of trade, sector vulnerability and dependency of foreign inputs.

To do so, the analysis focuses on two main elements: (i) the size and composition of inputs to a sector or commodity group; looking at total imports, foreign inputs to sectors (in value added), and embedded land and water use, and (ii) source countries' vulnerability to climate change

Methodology

Overview of data sources

The methodology is based on developments by Lager and Benzie (2022) to analyse Sweden's exposure to transboundary climate risk via trade. It has been adapted and expanded to the Nordic region. The analysis integrates three types of trade data inputs and one climate vulnerability index. The trade data comprise national toll logs (national imports of commodities as registered by national toll agencies), inputs to economic sectors in value added (from the World Input-Output Database: "WIOD"), and foreign inputs of embedded land and blue water use per sector (Exiobase, 3.7); see Table A.1. The latest available representative year was used for the analysis; 2019 for national toll statistics (due to effects of COVID-19 on the global markets, the year 2020 is treaded as an atypical year for trade flows) and 2014 for input-output and land and water use. The three trade datasets combined provide an overview of the latest updated and most comprehensive freely available trade data to analyse countries' and sectors' dependency on foreign inputs.

Table A.1. Trade data input overview and description

Trade data	Description	Unit	Year	Source
National toll statistics	National imports in goods, data gathered from each country's statistical database.	Total value: (in national currencies, translated to Euro*)	2019	National statistics agencies: DST (2021, Denmark); Tulli (2021, Finland), Statistics Iceland (2021), SSB (2021, Norway); SCB (2021, Sweden)
OECD's World-Input Output Data (WIOD):	Global input-output table depicting global trade in embedded inputs in value added. No data available for Iceland.	Total value (USD, translated to Euro*)	2014	WIOD (2021)
Resource footprints: Exiobase 3,7	Embedded land and blue water use	Land use: km2, water use: m3	2014	Environmental footprints (2021),

*Value conversion needed (to euro) for each year (yearly averages, middle rate used), data from ECB (2021) and Deutsche Bundesbank (2021) (for Iceland).

ND-GAIN is utilised to understand domestic climate vulnerability for the identified trading partners (ND-GAIN, 2021). The index combines data on countries' physical exposure to climate risk, dependency on climate sensitive systems and the capacity to adapt within six key systems: food, water and health provisions, ecosystems, human habitats and infrastructure. The climate vulnerability score for 2019 is used for the analysis and countries are graded on a six-tier colour scale, as shown in Table A.2.

Table A.2. Climate risk score ranking and colour codes used for the online tool

Climate risk	ND-GAIN	Colour
Very low risk	>70	
Low risk	65–70	
Medium risk	60–65	
Medium high risk	55–60	
High risk	50–55	
Very high risk	<50	
no value	no value	

Data availability

Due to data constraints, only Denmark, Finland and Sweden are represented across all datasets. While national toll data are available for all five countries, Norway and Iceland lack data on embedded land and water use, and Iceland is not specified in the OECD's input-output table, rendering the depth of analysis for each country uneven. This limitation is due to data constraints from the original datasets (WIOD and Exiobase). Where applicable toll data for Iceland have been adapted to reflect sector-specific climate risk, discussed more in depth below.

Understanding how trade data can (and cannot) be used for the assessment of climate risk

To understand what conclusions can be derived (and not) from a cross-sectoral data analyses like this, we need to understand the nature and composition of the trade data included in the analysis. The data components are included, as they give an overview of the sector inputs and can – if aptly interpreted – give us a first glance at input dependence from climate risky regions. It facilitates an understanding of the composition of the Nordic countries' economies, dependencies and interdependencies for the Nordic region, and help us identify sectors that are specifically exposed to climate risk via international trade. This section aims to aid the interpretation of the result of the analysis, for those who are previously unfamiliar with trade data structures.

Typically, national toll-based import and export data are used to understand trade flows on a national level (e.g. PwC, 2019). While using physical flows of commodities might seem an intuitively apt approach, it is misleading for linking production to consumption for many traded products (Croft et al., 2018; Steen-Olsen et al., 2016). This is because most exported goods are logged at the first port of entry or from the country of last processing, overlooking where the product inputs originally derive from (this is known as the "Rotterdam effect"[1]). The more tiers of processing a product goes through before consumption (i.e. the higher the complexity of the supply chain), the more difficult it is to derive the origin of the product and the more misleading national trade statistics are as a depiction of origin.

To illustrate with an example: The soy supply chain is an example of a semi-complex system, indicating that national trade statistics are not sufficient for a robust assessment of supply chain risks. According to UNCOMTRADE (the world's most comprehensive trade data compilation on national statistics) 60% of all Swedish soy is sourced from Norway, which has no commercial production of soy (OEC, 2021). This is because the majority of soy that is imported by Sweden travels through Norwegian ports (Swedwatch, 2012).

National toll statistics can still help us understand the compositions of inputs to a country and nature of the physical flows of trade, important trade hubs and potential partners for collaboration. As shown in slides 20–21, a significant number of traded commodities for the Nordic Countries derive from, are transported or processed via intra-Nordic trade, and this is especially withing the agriculture and food sector as well as energy imports.

To overcome the "first-tier" problematics (the Rotterdam effect), we include input-output data in value added (WIOD) and land and water use in the analysis. For input-output (WIOD) data in value added the emphasis is on the higher tiers of the supply chain (i.e. closer to the importer), which is typically where most value is added to imports (e.g. during the latter stages of manufacturing and assembly). Costs in labour input, especially in developed economies, are often significant, so later stages of production will generally heavily outweigh the value of the physical inputs themselves. For example, the value of the physical components in the Apple iPod is just a fraction of the total value of the final product (Dedrick et al., 2011). Lastly, the

1. This is known as the "Rotterdam effect" because such data give the impression that traded goods are "from" the last port they went through before arriving in the country in which they are consumed, despite the fact that most commodities and products are re-exported several times for processing or simply on their supply chain journey. For many European countries, such data might identify one of the major trade hubs, such as the port of Rotterdam, suggesting, for example, that Sweden's bananas "come from" Rotterdam.

emphasis of data on resource footprints is opposite to value added: resource inputs are highest at the early stages of the supply chain (last tier).

A second data constraint related to the number of countries/regions represented in available data sets and the limited availability of time sequences and recent updates for the input-output and land and water use data (as the modelling and assemblage is cumbersome). The WIOD dataset consist of 43 input regions, gathering the remainder of inputs to sectors in a "rest of the word" region.

To summarise the three data inputs advantages and limitations:

- National toll data has advantages in accounting for actual physical flows of commodities rather than modelled estimates. They offer comprehensive geographical coverage, but fall short in accounting for imports beyond the last country of entry or processing.

- Input-output table-based models estimate flows of inputs between economic sectors all the way down to the estimated origin. However, they often struggle with geographical coverage (aggregating smaller economies into "rest of the region" or "rest of the world" groups). A further challenge is acquiring accurate estimates, especially for developing economies, as the financial models are based on "typical" world sector performance.
- Footprint data (environmentally extended MRIO's) provide a resource-focused account of inputs to a country's consumption for different economic sectors. Such approaches inherit much of the modelling limitations of the input-output models.

The trade data "tool" developed for this analysis provide readers with the opportunity to interact with the different kinds of datasets, deep-dive into specific country-or sector content, and in this way familiarise themselves with the composition of trade for different data sets for the Nordic countries. See https://public.flourish.studio/story/1028351/.

Results: Climate risk in trade for the Nordics

Input-dependent sectors and highly traded commodities

The Nordic countries have both similarities and differences in the composition of major economic sectors, as well as input dependencies from foreign markets. Here we will explore some key components of trade for the Nordic countries and sector's that are specifically reliant on trade. Table A.3 provides a comparison for the numbers below:

- For Denmark the sector with the highest share of foreign input values in 2014 was the transport sector (27% of total traded inputs), followed by fairly equal inputs shares (8–10%) for retail trade, the electrical and machinery sector, finance and investments, and construction. The most imported commodities in 2019 (total value) was machinery and transport equipment (34%), non-classified products (17%), chemicals and plastic (12%), and food and live animals

(12%).

- Finland's composition of trade looks somewhat different (see slides 7 and 8). The largest foreign input values are to the Petroleum, chemicals and minerals sector in Finland (18%), followed by electrical and machinery sector (17%), finance and investments and construction (8% respectively). This is mirrored in the commodity imports mostly reported for the county: Petroleum, gas coal and coke and electricity (33%), non-classified products (15%), chemicals and plastics (12%), crude materials (except food and fuel) (8%) and metal and metal products (7%)
- Iceland's commodity imports are dominated (in total value) by machinery and transport equipment (34%) followed by near-equal inputs shares (9–12%) of petrol, gas coal and coke, non-classified products, crude materials (except food and fuel), and food and live animals.
- In Norway, most foreign value added is concentrated in the finance and investment sector (18%), followed by construction (13%), public health, education and defence (11%), and retail trade and the transport sector (10%, respectively). The most imported commodities are machinery and transport equipment (40%), non-classified products (15%), chemicals and plastics (10%), metal and metal products (9%), and food and live animals (6%).
- Sweden's composition of foreign inputs shows the largest distribution across sectors, with a fairly equal share of foreign inputs to the top five sectors (9–12%): electrical and machinery (12%), transport (12%), finance and investments (11%), petroleum, chemicals and minerals (11%) and transport equipment (9%). Commodity imports are more concentrated: machinery and transport equipment (39%), non-classified products (13%), chemicals and plastics (11%), petroleum, gas coal and coke and electricity (11%), and food and live animals (10%)

For **all three countries** with available data on embedded land and water use –Denmark, Finland and Sweden – agriculture (including forestry and fishing) and food production combined account for up to half of total inputs (a combined 49% of total land and 43% embedded water use for Denmark, 48% of land and 44% of water use in Finland, and 43% of land and 44% of water use for Sweden); see slides 3, 7 and 16.

Table A.3. Table of comparison of the top-5 sectors for each data category, for the five Nordic countries.

Country	rank	Commodity trade (most imported products)	% of total	Sector inputs (sectors with highest input values)	% of total	Land and water use (sectors with highest land/water use)	% of total
(land/water)							
Denmark	1	Machinery and transport equipment	34%	Transport sector	27%	Food production	26/23%
	2	Non-classified products	17%	Retail trade, maintenance and service industries	10%	Agriculture, forestry and fishing	23/20%
	3	Chemicals and plastics	12%	Electrical and machinery	9%	Public health, education and defence	12/15%
	4	Food and live animals	12%	Finance and investments	9%	Construction	11/5%
	5	Metal and metal products	7%	Construction	8%	Electricity, gas and water	0,5/11%
Finland	1	Petroleum, gas coal and coke and electricity	33%	Petroleum, chemicals and minerals	18%	Agriculture, forestry and fishing	37/27%
	2	Non-classified products	15%	Electrical and machinery	17%	Food production	11/17%
	3	Chemicals and plastics	14%	Finance and investments	10%	Public health, education and defence	13/16%
	4	Crude materials (except food and fuel)	8%	Metal and metal products	8%	Construction	21/6%
	5	Metal and metal products	7%	Construction	8%	Finance and investments	5/6%
Iceland	1	Machinery and transport equipment	35%	-	-	-	-
	2	Petrol, gas coal and coke	12%	-	-	-	-
	3	Non-classified products	12%	-	-	-	-
	4	Crude materials (except food and fuel)	11%	-	-	-	-
	5	Food and live animals	9%	-	-	-	-

Norway	1	Machinery and transport equipment	40%	Finance and investments	18%	-	-
	2	Non-classified products	15%	Construction	13%	-	-
	3	Chemicals and plastics	10%	Public health, education and defence	11%	-	-
	4	Metal and metal products	9%	Retail trade, maintenance and service industries	10%	-	-
	5	Food and live animals	6%	Transport sector	10%	-	-
Sweden	1	Machinery and transport equipment	39%	Electrical and machinery	12%	Agriculture, forestry and fishing	29/23%
	2	Non-classified products	13%	Transport sector	12%	Food production	14/21%
	3	Chemicals and plastics	11%	Finance and investments	11%	Construction	14/4%
	4	Petroleum, gas coal and coke and electricity	11%	Petroleum, chemicals and minerals	11%	Public health, education and defence	9/12%
	5	Food and live animals	10%	Transport equipment	9%	Wood, paper and publishing	5/1%

Table A.4. Overview of the total of high-risk shares of inputs for the key five sectors, embedded inputs in value added (WIOD, no data available for Iceland).

Sectors – high climate risk. Top 5 share of high-risk inputs to sectors (in value added)	DNK	FIN	NOR	SWE	average
Transport	38.5%	15.8%	24.8%	9.5%	22.1%
Food production, beverages and tobacco	17.9%	17.0%	24.5%	14.6%	18.5%
Agriculture and hunting	16.6%	18.0%	13.3%	14.0%	15.5%
Finance and investment	22.4%	15.6%	15.2%	7.8%	15.2%
Petroleum, chemicals and minerals (non-metallic)	11.3%	13.4%	20.9%	15.0%	15.2%

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About this publication

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Current knowledge and pathways for action

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