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Climate risk and the Norwegian exchange rate

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Abstract

This study discusses whether climate risk, in the form of physical risk and transition risk, may cause an appreciation or depreciation of the Norwegian krone. Exchange rates reflect relative prices between money, goods, and services of different countries. Since countries vary greatly in their exposure to and capacity to manage different types of climate risk, assessing the exchange-rate impact of climate risk entails evaluating how much a country may lose or gain from climate risk compared to its trading partners. The study highlights several factors suggesting that the Norwegian krone may face lower climate risk over time compared to the currencies of trading partners. It also investigates empirically whether climate risk has affected the krone exchange rate over the past decade. The results suggest that climate risk has not contributed to fluctuations in the krone exchange rate over the examined period.

Keywords: Climate risk, stranded assets, exchange rates, green transition.

JEL codes: *Q54, Q56, Q58, F31, F37.*

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1 Introduction

The scope and nature of the production and consumption of goods and services since the Industrial Revolution have led to significant changes in the world's climate, including rising global temperatures and more frequent extreme weather events.[1] Ongoing and projected climate change is generally believed to be negative for ecosystems, biodiversity, and human welfare. Temperature increases and extreme weather events can affect economic production and growth due to their effects on natural resources and on real and human capital, for example, in the form of destruction of infrastructure and a decline in labour productivity.

Moreover, demand for and production of climate-friendly goods and services have increased over time, in line with growing environmental awareness, technological and economic opportunities, and government regulations. Changing consumption and production patterns may reduce the value of carbon-intensive resources and of products and services linked to their extraction and consumption. Several studies have concluded that reducing the extraction and consumption of carbon-intensive resources such as coal, oil, and gas is necessary to achieve national and international climate goals, including the Paris Agreement's goal of limiting the global temperature increase to well below 2 degrees; see, for example, Muttitt (2016), Rogelj et al. (2018), Asheim et al. (2019), and Welsby et al. (2021).[2]

Reduced extraction and consumption of carbon-intensive products as a result of regulations, changes in technology, and/or shifts in consumer preferences could impact external balances, public finances, and other economic sectors of countries with extensive carbon-intensive resources; see e.g. Semieniuk et al. (2022). Norway is one of the world's largest petroleum exporters and has substantial remaining petroleum resources.[3]

[1] For more detailed documentation, see e.g. the websites of NASA (https://climate.nasa.gov/), Berkeley Earth (https://berkeleyearth.org/), and the UN Intergovernmental Panel on Climate Change (https://www.ipcc.ch/).

[2] The governments of almost all countries in the world have signed the 2015 Paris Agreement, committing themselves to working actively to keep global warming well below 2 degrees (Celsius), and preferably close to 1.5 degrees, compared to the average temperature until approximately the latter half of the 1800s ('pre-industrial era'). For further information on the Paris Agreement, see https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

[3] https://worldpopulationreview.com/country-rankings/oil-reserves-by-country

Some studies imply that, like several other commodity currencies, the Norwegian krone will depreciate over time as a result of climate risk-motivated restrictions on fossil resources or lower demand for such resources; see Kapfhammer et al. (2020), Aune et al. (2020), and Benedictow and Hammersland (2023). The analysis in this study suggests that this conclusion may be based on a rather narrow and static perspective on the Norwegian economy, one that also does not sufficiently account for the effects of climate risk on the economies of trading partners and their responses over time.

This study discusses the possible effects of climate risk on the krone exchange rate, both the real krone exchange rate in the long run and the nominal krone exchange rate in the short run. Exchange rates are relative prices where nominal exchange rates can be regarded as relative prices of money between countries, while real exchange rates express relative prices of goods and services between countries in a common monetary unit.

To assess how climate risk might affect the krone exchange rate, we need to make assumptions about how climate risk could impact the Norwegian economy both at the aggregate level and over time relative to the economies of its trading partners. Focusing on the current sectoral composition across countries or on developments in individual sectors over time may give a biased impression of the significance of climate risk for exchange rates. While some industries may decline as a consequence of climate risk-related changes in consumer preferences and policies, other industries may experience an upswing as a result of changing market conditions and policies.

How and how much an economy will be affected by climate risk will depend on the type of climate risk it faces over time and the economy's resources to manage such risk. Countries have different exposures to different types of climate risk, and differing resources to manage them. In general, factors with a symmetrical impact on the Norwegian economy and the economies of its trading partners are unlikely to cause changes in the krone exchange rate. However, factors that contribute to a worse (or more favorable) outcome for the Norwegian economy compared to its trading partners could weaken (or strengthen) the krone exchange rate, all else being equal.

As regards a possible phase-out of carbon-intensive resources and its impact on the krone exchange rate, it is also important to consider replacement forms of energy, which will presumably be adopted at varying speeds and degrees in different countries. It can be argued that replacing carbon-intensive energy sources with renewable energy sources can lead to a reduction in energy and production costs over time; see Way et al. (2022) and Adrian et al. (2022). Several studies have pointed to significant scale and learning effects in the production of renewable energy; see Lazard (2024), Roser (2020), and references therein. Such effects may further reduce renewable energy production costs as more renewable energy is produced. This contrasts with production costs linked to non-renewable energy, which may rise or remain stable as remaining resources are depleted. Countries that adopt renewable energy sources may consequently achieve greater savings per unit of energy than those that continue to primarily use non-renewable energy. It also follows that exporters of carbon-intensive energy sources, who simultaneously produce or utilise renewable energy, may be able to partly or wholly offset any capital losses on their carbon-intensive energy resources.

In our analysis, we point to aspects of climate risk that could potentially have a greater or lesser negative impact on the Norwegian economy than on the economies of its trading partners. The analysis suggests that the Norwegian krone has relatively low climate risk exposure due to Norway's geographical location, OECD-dominated foreign trade and investment, a relatively low and declining share of remaining petroleum resources relative to other components of national wealth, and, not least, a higher pace of green transition compared with many of Norway's trading partners.

The study is structured as follows: Chapter 2 distinguishes between different types of climate risk and points to differences between the exposure and vulnerability of different regions and countries to climate risk. Chapter 3 gives an overview of Norway's and its trading partners' national wealth and discusses the exposure of various wealth components to climate risk. Chapters 4 and 5 focus on the climate risk facing Norway's financial resources, in the form of the Government Pension

Fund Global (GPFG), and petroleum resources, respectively.[4] Chapter 6 discusses possible comparative advantages for countries that adopt climate-friendly products and energy sources at a faster pace and to a greater extent than others. Chapter 7 investigates econometrically whether climate risk has impacted the nominal effective krone exchange rate, based on data since 2010. Finally, Chapter 8 summarises the implications for the krone exchange rate.

2 Types of climate risk and their distribution

Climate risk can be broadly divided into physical risk and transition risk.[5] Physical risk is associated with harm to nature, life, and property as a result of climate change. Transition risk is associated with asset depreciation and increased production, distribution, and consumption costs as a result of climate risk-related changes in preferences, technology, and public regulatory activity.

At the global level, transition risk appears to be concentrated in developed economies with relatively high per capita energy consumption, while exposure to physical climate risk is mainly observable in emerging economies; see Figure 1, Hickel (2020), Ferrazzi et al. (2021), and Shaw et al. (2022).[6] Most developed economies are therefore more exposed to the risk of changes in production, distribution, and consumption patterns intended to reduce greenhouse gas emissions. In contrast, most emerging economies are more exposed to physical climate risk and have limited capacity to manage it.

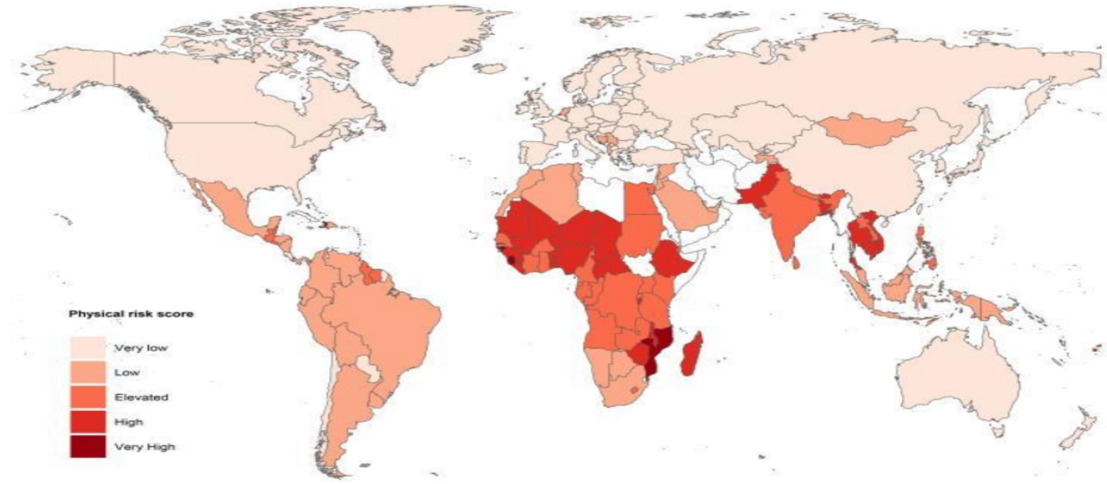
Figure 2 compares the vulnerability of selected countries to physical climate risk in the period 1995–2020. Such vulnerability is linked to both the countries' exposure and their capacity to manage physical risk; see Cheema-Fox et al. (2021).[7] Norway's

[4]These chapters draw heavily on Akram (2024).

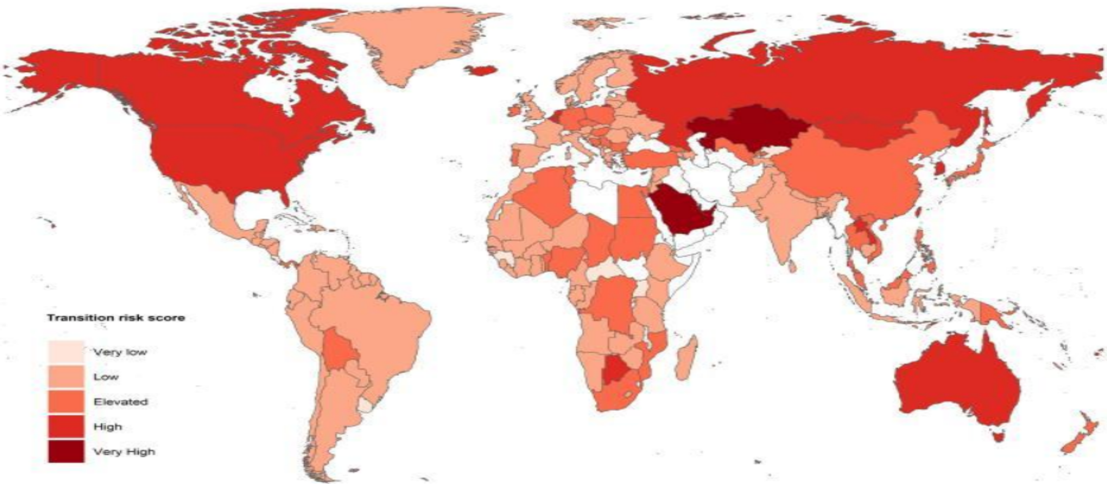
[5]Climate risk can also include liability risk. This includes possible damages claims relating to corporate or official decisions, or lack thereof, which can be linked to climate policy or climate change. In qualitative terms, the exchange-rate impact of potential international damage claims may be similar to a reduction in the value of carbon-intensive resources.

[6]https://www.eib.org/attachments/efs/economics_working_paper_2021_03_en.pdf and https://www.eib.org/en/stories/climate-change-risks-developing-countries.

[7]For details and data, see https://gain.nd.edu/our-work/country-index/methodology/. The IMF's INFORM Risk Index also gives the same impression; see https://climatedata.imf.org/pages/fi-indicators.



(a) *(a) Physical climate risk faced by different countries.*

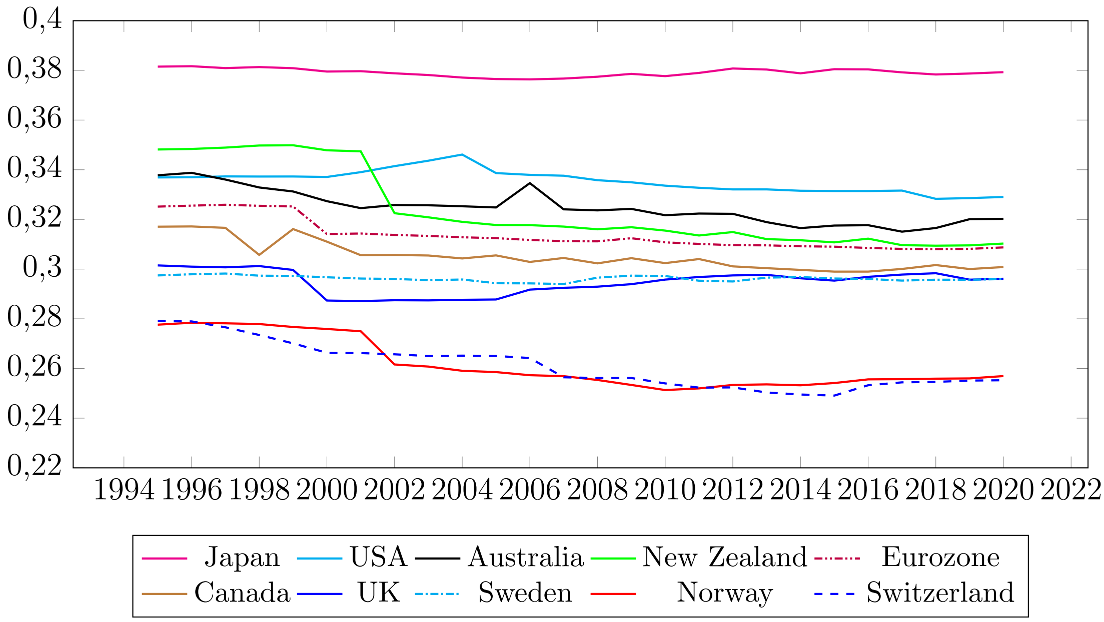


(b) *(b) Transition risk faced by different countries.*

Figure 1: *Physical and transition risks across countries and regions. Figure source: Ferrazzi et al. (2021).*

vulnerability is relatively low because it has both low exposure to physical climate risk and relatively strong economic and governance capacity to manage it.

Figure 2 indicates that Norway has had lower vulnerability to physical climate risk than many developed and emerging economies over the sample period. The figure also indicates small differences in physical climate risk vulnerability between the G10 countries. Emerging economies feature greater differences in climate risk vulnerability. The stability in indicator values for the various countries throughout the data period suggests that the indicator values are dependent on factors which change slowly. Countries' rankings based on physical climate risk may therefore remain stable over long periods of time.



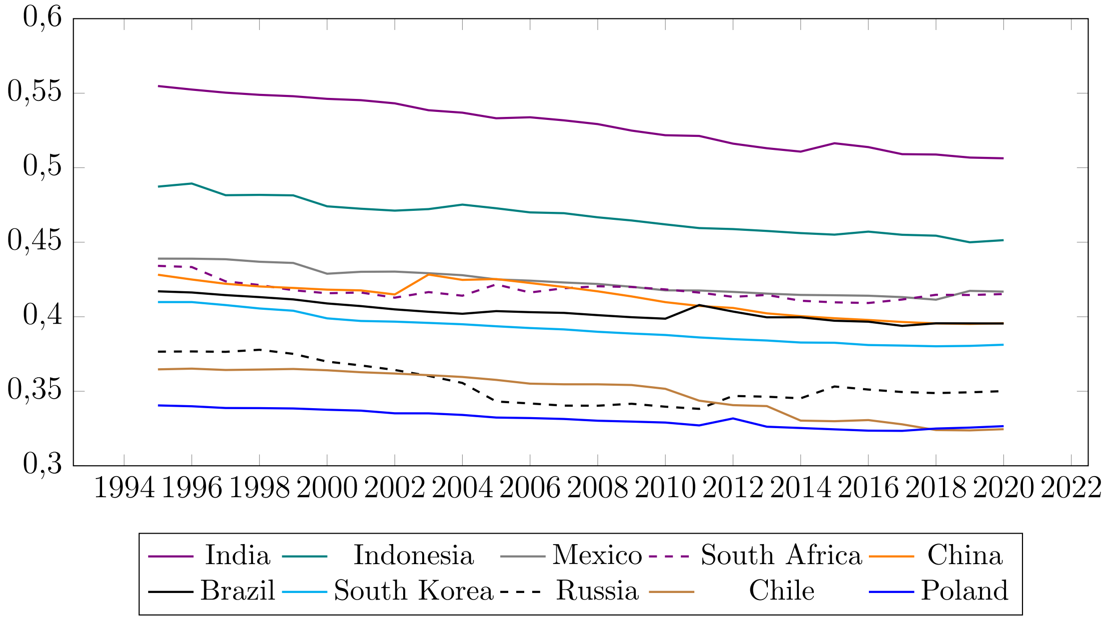


Figure 2: *Indicator values (ND-Gain) for physical risk in selected countries in the period 1995–2020. The top panel shows indicator values for selected advanced economies, while the bottom panel shows indicator values for the BRICS countries and selected emerging economies over the same period. Low values indicate low exposure to physical risk and/or good management capacity. Data source: https://gain.nd.edu/our-work/country-index/rankings/.*

Furthermore, European countries appear to face lower transition risk than many countries in other regions; see Ferrazzi et al. (2021) and Winkler (2022). For example, countries like the USA, South Africa, China, and India appear to face both higher physical risk and higher transition risk than most countries in Europe; cf. Figures 1 and 2.

When entire economies, rather than individual sectors, are considered, Norway is among the countries which face both relatively low physical risk and low transition risk; see Figure 1 and Winkler (2022). On the other hand, when the selected countries are ranked according to the share of GDP accounted for by petroleum revenues, Norway appears to face relatively high transition risk. Petroleum revenues have accounted for around 20% of Norway's GDP in recent years.[8]

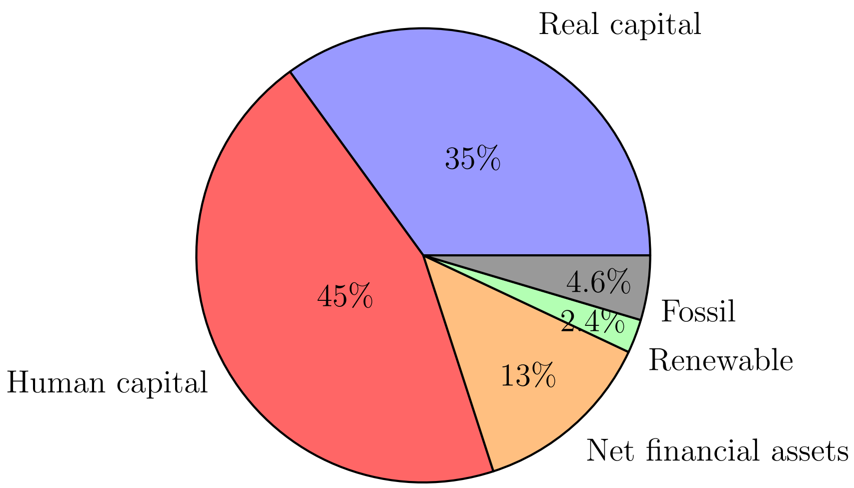
However, when discussing the potential impact of different types of climate risk on the krone exchange rate, it is more useful to consider the future development of the Norwegian economy as a whole relative to the economies of its trading partners, rather than focusing on the current industry and income conditions in Norway and abroad. The composition of countries' national wealth can provide perspective on future income flows from various wealth components. The next chapter discusses how climate risk may affect the various components of Norway's national wealth.

3 Exchange rates, national wealth and climate risk

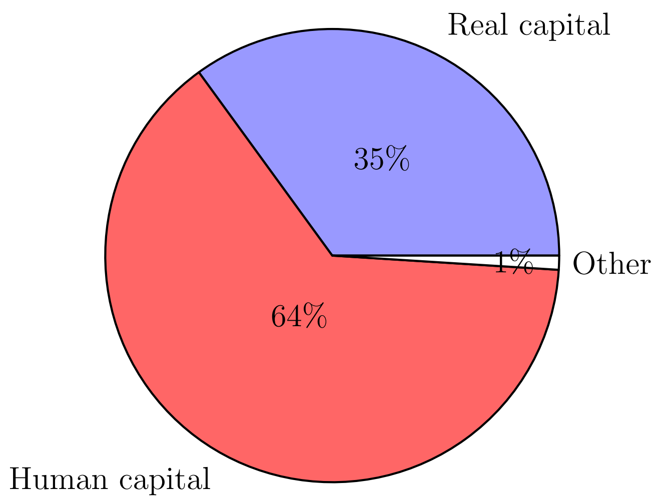
Real exchange rates are nominal exchange rates adjusted for price differences between countries. Relative differences between countries related to their exposure to and capacity to manage different types of climate risk will affect the impact of climate risk on the real exchange rate between them. Real exchange rates between countries may not change if those countries are affected symmetrically and adapt similarly to climate risk. Differences between countries related to the distribution of national wealth between different resource categories can shed light on the potential impact of climate risk on the development of the Norwegian economy compared to the economies of its trading partners, and thus on the real exchange rate between them. The composition of a country's national wealth is an indicator of future income flows from the country's various resource sources.

Real exchange rates are affected by countries' net claims on each other, as well

[8] See https://www.norskpetroleum.no/okonomi/statens-inntekter/.



(a) *Norway*



(b) *OECD high-income countries*

Figure 3: *Comparison of national wealth composition between Norway and high-income countries in the OECD for year 2018. These include Norway's main trading partners. Data source: World Bank (2021).*

as by differences in productivity or growth between them over the long run; see e.g. Obstfeld and Rogoff (1996) and Itskhoki (2021). The nominal or real value of the krone can be expected to rise when Norway's net foreign assets increase and if productivity growth in Norway exceeds productivity growth abroad. To assess how different types of climate risk could affect the exchange rate, we need to make assumptions about how the various components of national wealth may be affected by climate risk and the possible implications of this for Norway's net foreign assets and productivity growth relative to its trading partners.

Figure 3.a provides an overview of Norway's national wealth.[9] The various components of national wealth represent the present value of expected income flows from human, real, financial, and natural capital over a period of 50 years from 2018. The estimates in the figure indicate that most of Norway's national wealth consists of real and human capital, 35% and 45%, respectively. Financial capital in the form of net foreign assets primarily comprising the GPFG, accounts for around 13%, while remaining petroleum resources (fossil resources) account for a relatively small share of national wealth, less than 5%; see World Bank (2021). The value of the GPFG is the result of investment abroad of public revenues from petroleum activities, and returns on these investments.

The composition of Norway's national wealth differs substantially from those of its trading partners, which are primarily high-income countries in the OECD. Compared to these countries, Norway has a larger share of net financial assets abroad and of fossil natural resources. Figure 3.b and Table 1 suggest that the national wealth of Norway's largest trading partners consists mainly of real and human capital. While the share of real capital in Norway is comparable to that of its trading partners, the share of human capital is considerably lower, more than 25 percentage points lower than that of the US and China. Major petroleum producers like Kuwait and Saudi Arabia differ from other countries in that more than 45% of their national wealth comprises petroleum resources; see Table 2.

Table 1: *Composition of national wealth of Norway's main trading partners*

	SWE	DNK	DEU	NLD	FRA	UK	USA	CHN
Real capital	0,38	0,36	0,38	0,34	0,40	0,34	0,30	0,22
Human capital	0,58	0,58	0,57	0,60	0,60	0,66	0,71	0,73
Net financial assets	0,01	0,04	0,04	0,05	-0,01	-0,01	-0,03	0,01
Natural capital	0,03	0,01	0,01	0,01	0,01	0,01	0,02	0,04
Fossil	0,000	0,003	0,000	0,004	0,000	0,002	0,005	0,009

Note: Based on 2018 data from World Bank (2021). For further information, see https://www.worldbank.org/en/publication/changing-wealth-of-nations.

[9] Data are for 2018 and are from the World Bank: https://www.worldbank.org/en/publication/changing-wealth-of-nations/data. The estimates and calculation method used for the various components differ from official Norwegian calculations; see e.g. https://www.regjeringen.no/no/dokumentarkiv/regjeringen-solberg/fin/beregning-av-norges-nasjonalformue-til-perspektivmeldingen-2017/id2548710/. The World Bank's calculations facilitate comparison of the sizes of different wealth components across countries and over longer time periods.

Table 2: *Composition of national wealth of selected resource-rich countries*

	CAN	AUS	ZAF	IND	BRA	RUS	KWT	SAU
Real capital	0,29	0,37	0,31	0,25	0,27	0,45	0,12	0,21
Human capital	0,65	0,57	0,57	0,65	0,63	0,35	0,14	0,23
Net financial assets	0,02	-0,04	0,01	-0,02	-0,02	0,01	0,27	0,10
Natural capital	0,05	0,10	0,11	0,12	0,13	0,19	0,46	0,47
Fossil	0,013	0,020	0,038	0,021	0,012	0,123	0,458	0,458

Note: Based on 2018 data from World Bank (2021). For further information, see https://www.worldbank.org/en/publication/changing-wealth-of-nations.

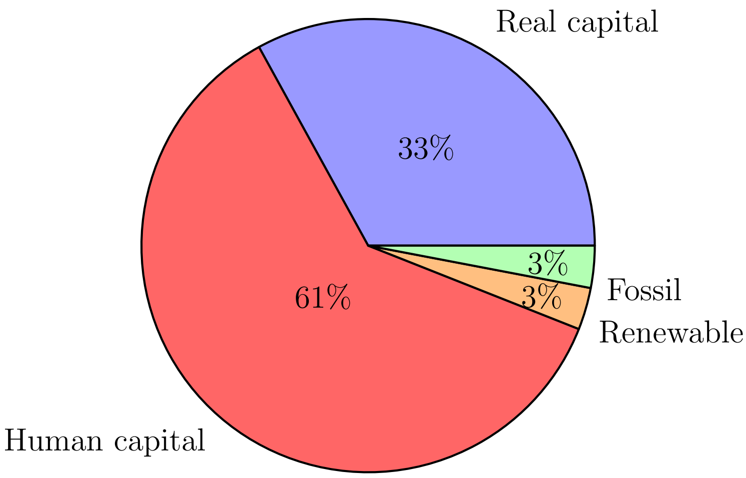


Figure 4: *Composition of Norway's national wealth in 1995. Data source: World Bank (2021).*

The composition of national wealth can change over time as a result of resource discoveries and economic and political changes, and such developments may alter a country's exposure to climate risk. Figure 4 reminds us of the composition of Norway's national wealth in 1995, which was broadly comparable to that of its trading partners both then and more recently; cf. Table 1. Net financial assets were virtually zero, while petroleum resources (at 3%) were one of the factors which distinguished Norway from its trading partners. Since 1996, the saving of petroleum resources abroad, in the GPFG, and the fiscal policy rule for the use of petroleum revenues (introduced in 2001), have contributed to an increase in the share of net financial assets. Despite this, the share of petroleum resources has grown over time as a result of new discoveries and increases in value.

The next section discusses the possible effects of climate risk, particularly physical climate risk, on real and human capital in Norway and abroad. Physical climate risk may impact real and human capital by contributing to higher capital depreciation rates and lower labour productivity. The differences in the effects of physical climate risk on national wealth across countries may be sizable, given that human and real capital are the largest components of most countries' national wealth; cf. Tables 1–2.

3.1 Physical risk, adaptation costs and productivity

Physical climate risk may impose both acute and ongoing costs. High exposure to physical climate risk implies high expected losses of natural, real, and human capital. It also implies the use of resources to protect against such losses and to maintain various types of natural and real capital which may depreciate faster than otherwise due to weather events. Real investments in infrastructure, buildings, and machinery that may be more resilient to weather events can increase real capital costs on a permanent basis. Moreover, degradation and loss of natural and real capital, as well as production stoppages, may reduce the productivity of capital and labour. This in turn may lead to higher production costs per unit of goods and services.

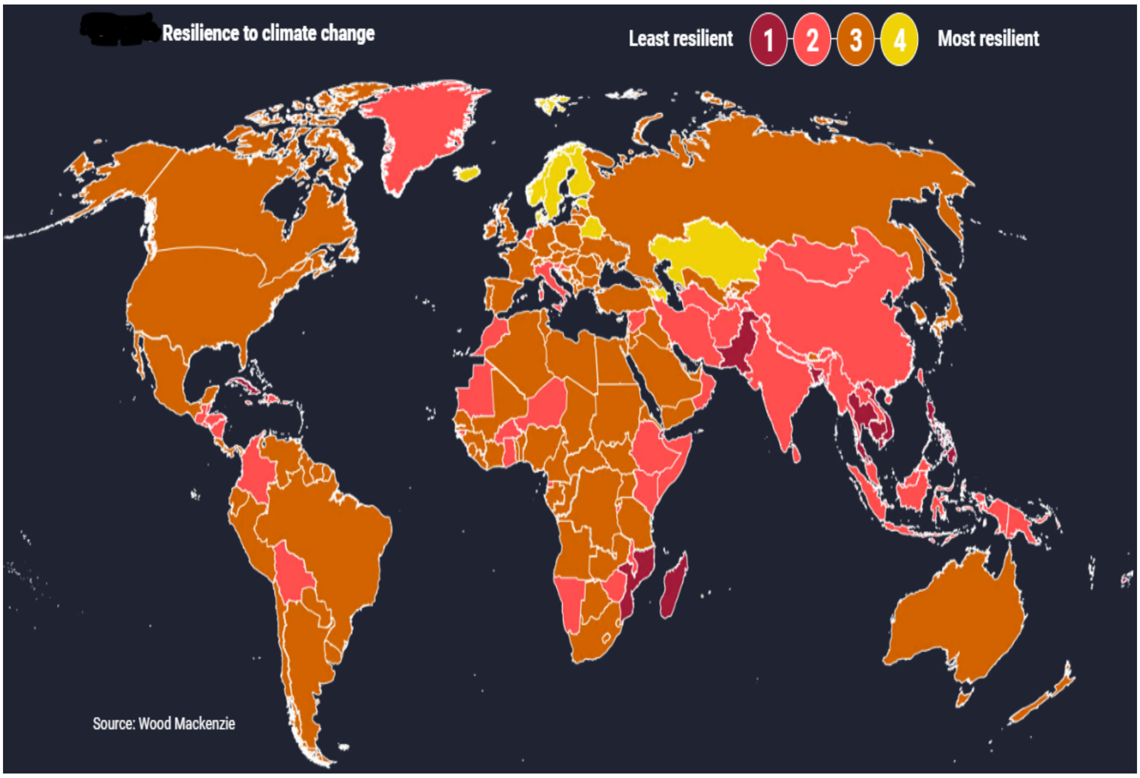


Figure 5: *Resilience of different countries to physical climate risk. Figure source: Martin and Zhou (2022).*

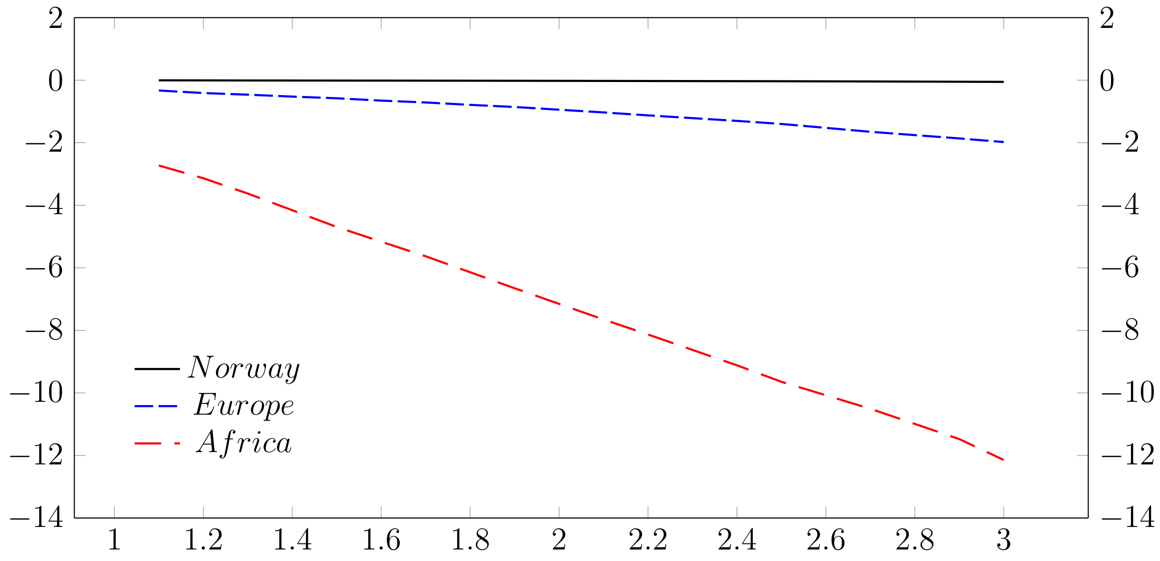


Figure 6: *Median estimate of percentage change in labour productivity in Norway, Europe, and Africa at different temperature levels above the average pre-industrial temperature in degrees Celsius. Data souce:* https://climate-impact-explorer.climateanalytics.org/.

Since the Norwegian economy may be less exposed and vulnerable to physical climate risk than most other economies, it faces lower costs associated with physical climate risk than many of its trading partners; see Figure 5. Norway's relative resilience with respect to physical climate risk is attributable to its geographical circumstances, industrial structure, and level of economic development. These factors imply that the productivity of labour and capital in Norway may not decline as much as that of its trading partners in response to harms to nature, real, and human capital.

On the contrary, labour productivity may rise slightly in Norway as a consequence of an increase in temperature. Several studies have reported a non-linear relationship between labour productivity and temperature, where an increase in temperature up to certain levels may raise labour productivity, but it may fall if temperatures rise beyond those levels. For analyses of the relationship between temperature and labour productivity; see e.g. Seppänen et al. (2006), Somanathan et al. (2021), Heal and Park (2016) and references therein.

Estimates suggest that labour productivity in Norway will not be significantly affected by global temperature rises; see Figure 6. This contrasts with the implications for several countries in Europe and, especially, Africa.

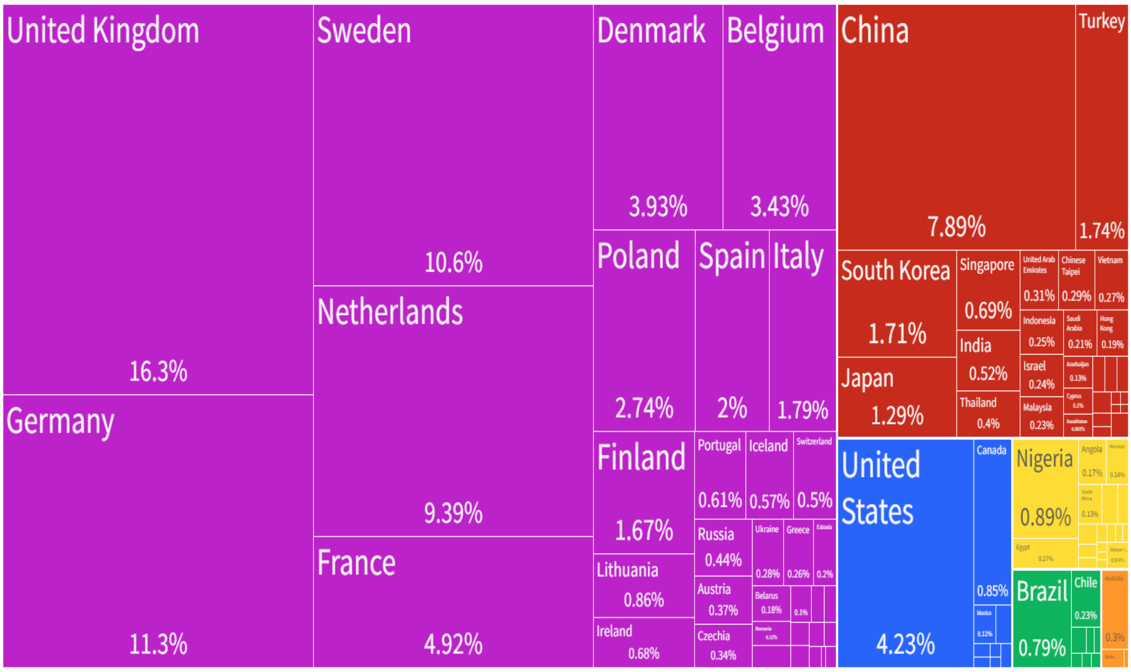


Figure 7: *Norway's exports of all goods and services to various countries in 2020. Figur source:* *http://wits.worldbank.org/visualization/detailed-country-analysis-visualization.html* .

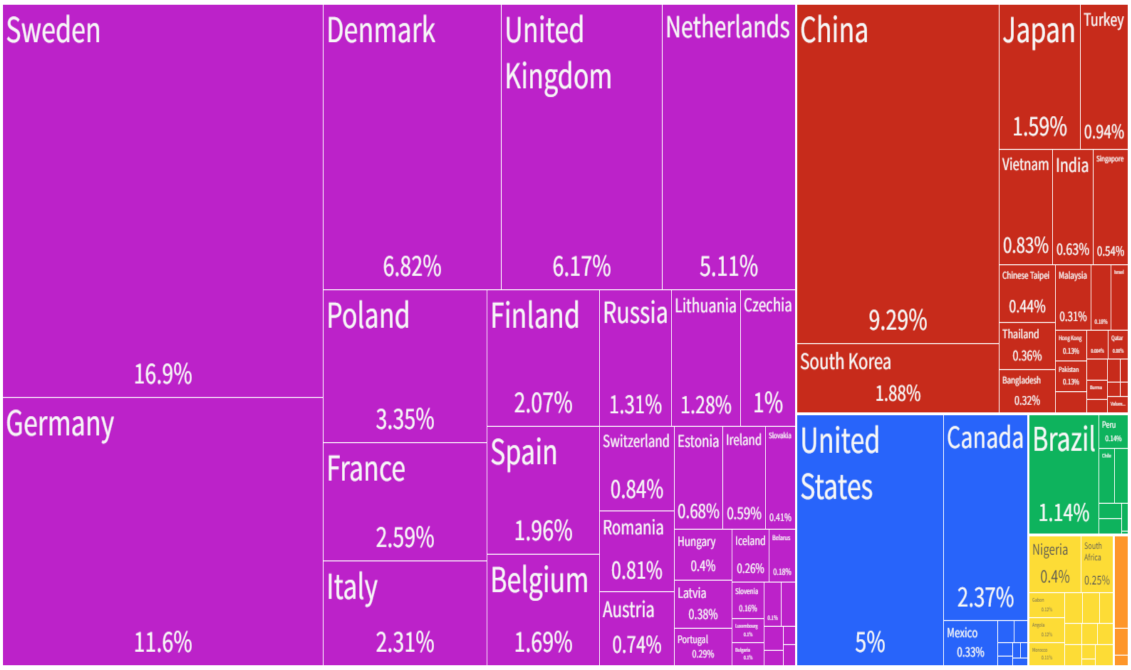


Figure 8: *Norway's imports of all goods and services from various countries in 2020. Figure source:* *http://wits.worldbank.org/visualization/detailed-country-analysis-visualization.html* .

Furthermore, Norway appears to have limited indirect exposure to physical climate risk due to the pattern of its foreign trade; see Figures 7 and 8. Most of Norway's trade is with other countries in the northern hemisphere, which have relatively little exposure to physical climate risk. However, Norway's trading partners may be exposed to physical climate risk to a greater extent than Norway due to their substantial trade with countries in the southern hemisphere.[10]

As trading partners have a greater degree of direct and/or indirect exposure to physical climate risk than Norway, the Norwegian krone may appreciate against their currencies, all else being equal.

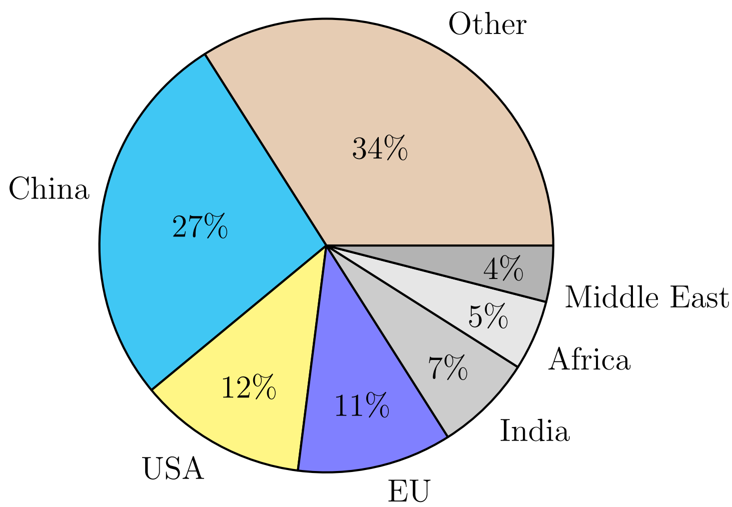
3.2 Transition risk and costs

Transition risk is associated with changes in the production, delivery, and use of energy to achieve climate goals. It involves investments in the production of climate-friendly energy and in associated real capital, including infrastructure, buildings, and machinery. It also entails adopting climate-friendly production processes, along with the production and consumption of climate-friendly goods and services. In particular, the production and use of fossil energy may decline and be phased out over time.

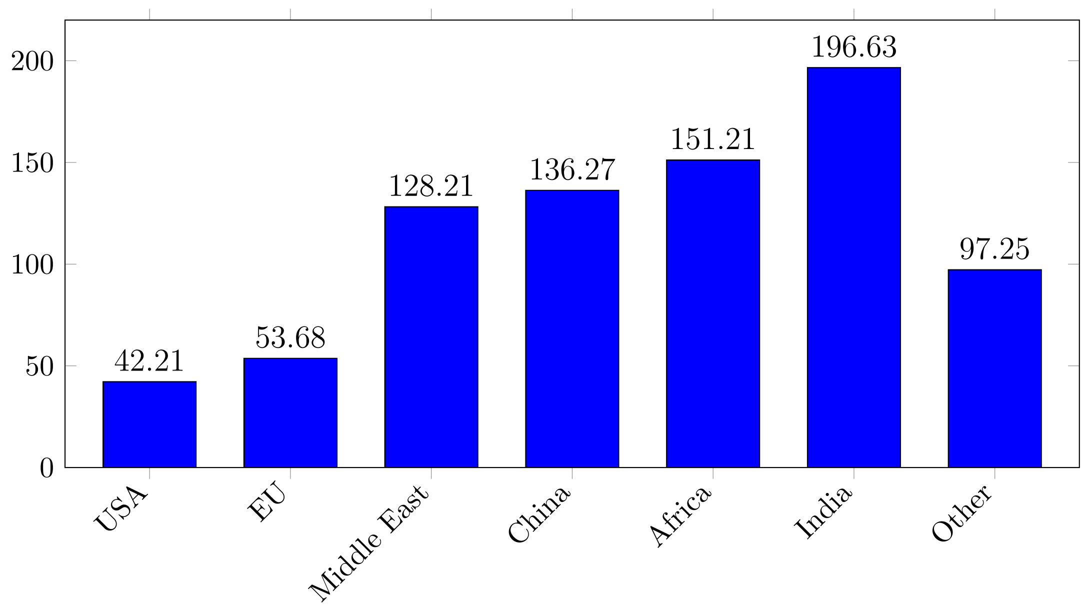
However, a fall in the value or phasing out of fossil energy resources does not necessarily entail a depreciation of the exchange rates of countries with such resources. Both countries with fairly large and countries with fairly small fossil energy resources face significant transition costs. Martin and Zhou (2022) has estimated that transition costs necessary to achieve the 1.5 degree temperature target under the Paris Agreement could total more than USD 75 trillion globally in the period 2020–2050. Figure 9 shows the distribution of these costs across different regions and countries. It is clear that not only major producers, but also consumers, of fossil energy resources could face transition costs as a result of climate change and official climate goals.

There are significant differences between countries in terms of how much they need to restructure their energy production and/or consumption in order to achieve international climate goals. Transition costs may be high in countries where the production and consumption of goods and services is highly dependent on fossil

[10] See e.g. https://viz.ged-project.de/ for analyses of international trade flows.



(a) *Distribution of total costs, in percent.*



(b) *Distribution of costs relative to GDP, in percent.*

Figure 9: *Distribution of estimated costs (USD 75 trillion) in the period 2020–2050 associated with achieving the 1.5-degree target, by country and region. (b) Distribution of estimated costs relative to the GDPs of countries and regions in 2020. Data sources: Martin and Zhou (2022) and IMF:* `https://www.imf.org/external/datamapper`.

energy sources. In addition, changes in technology and consumer preferences may promote the production and consumption of climate-friendly goods and services at the expense of those which are not, regardless of official climate goals and measures. Countries that produce fossil energy and whose production and consumption of goods and services are particularly dependent on fossil energy may experience a decline in the value of their energy resources and real capital.

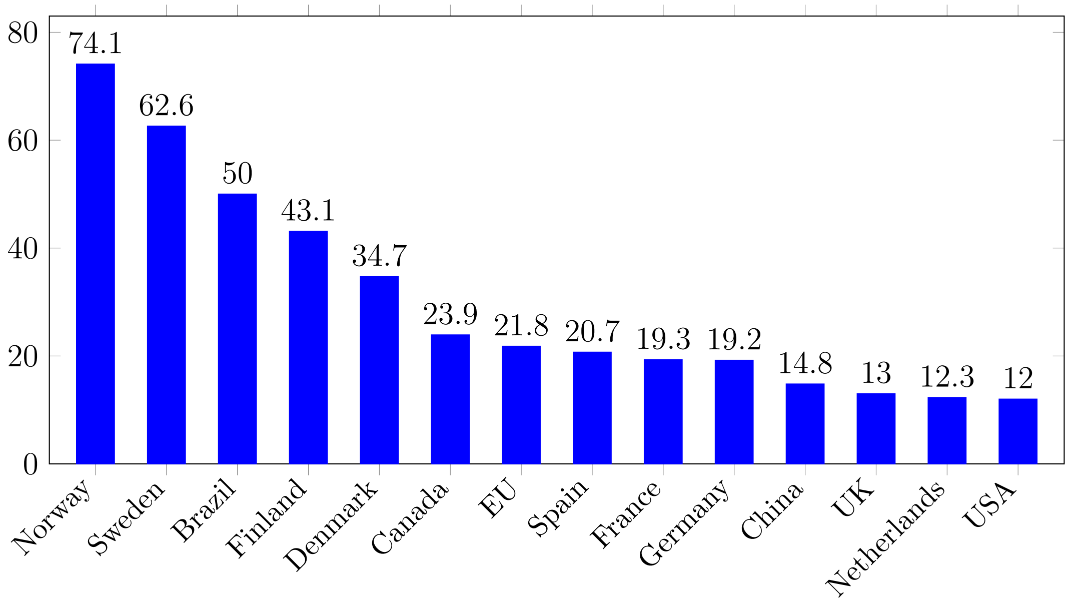


Figure 10: *Consumption of renewable energy as a percentage of total energy consumption in 2021. Data for Canada, China and Brazil relate to 2020, and have been obtained from the World Bank: https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS. Data for other countries are from Eurostat, from the ONS for the UK, and from https://usafacts.org/ for the USA.*

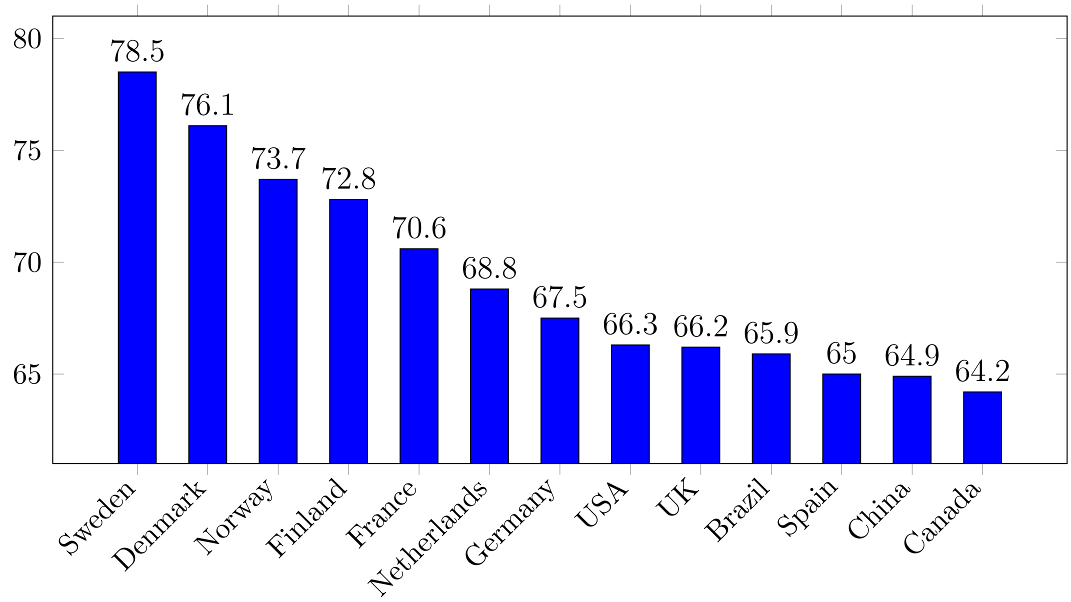


Figure 11: *The energy transition index (ETI) assesses the climate-friendliness of countries' energy systems and their readiness for sustainability-focused transition. The scale is from 0 to 100. Data source: https://www.statista.com/statistics/1120015/energy-transition-index-score-country-globally/.*

Norway's transition needs may be less than those of many of its trading partners, despite its relatively large petroleum resources. Most production and consumption of goods and services in Norway already rely on renewable energy. Figure 10 shows that the share of energy consumption based on renewable energy is higher in Norway than in its main trading partners. This significantly contributes to Norway's high score on the index for readiness for transition, positioning it as more prepared for transition than most of its trading partners; see Figure 11. However, Norway's sizable petroleum resources result in it being ranked lower than Sweden and Denmark on the World Economic Forum's Energy Transition Index (ETI); see e.g. World Economic Forum (2023).

In many of Norway's trading partners, transportation, heating, and industrial production are heavily dependent on fossil energy sources. This equates to a need for extensive restructuring of energy production, supply, and consumption in the years ahead if climate goals are to be achieved. For example, Germany's large car industry is based on internal combustion engines, which are due to be largely phased out over the next decade. This illustrates that extensive restructuring may occur on the demand side of fossil energy before fossil energy production, particularly of gas, falls significantly.

Norway's petroleum resources entail transition costs for Norway related to the potential phasing-out of these resources over time or due to a possible loss of value on remaining petroleum resources if demand shifts away from them. However, the transition risk associated with Norway's petroleum resources can be expected to decrease as the resources are transformed into well-diversified financial assets in the Government Pension Fund Global (GPFG). Before discussing the petroleum resources and the risk that some of them may remain on the seabed, we take a closer look at the climate risk facing Norway's financial resources.

4 Norway's financial assets and climate risk

Norway is also exposed to global physical and transition climate risks through the GPFG's foreign investments. These financial resources are more than five times greater than the petroleum resources that are part of Norway's national wealth, according to recent official estimates.[11] The value of the GPFG stems from foreign

[11] https://www.regjeringen.no/no/tema/okonomi-og-budsjett/norsk_okonomi/bruk-av-oljepenger-/hvor-stor-er-petroleumsformuen/id484903/ and https://www.nbim.no/no/.

investments of public revenues derived from petroleum activities and the returns on these investments; see Figure 12. The GPFG accounts for most of the public sector's net foreign assets and Norway's total net foreign assets; see Figure 13.

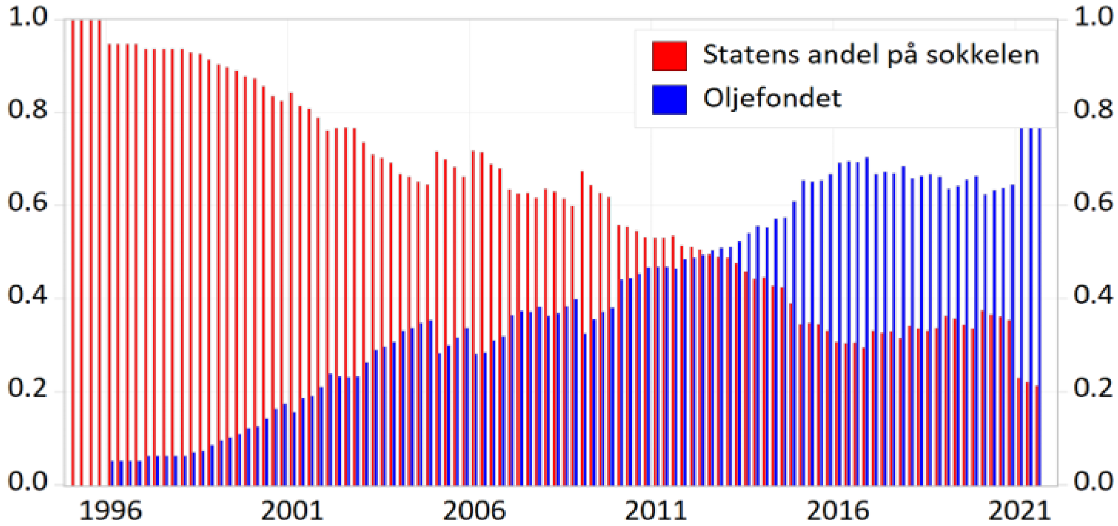


Figure 12: *Conversion of petroleum resources into financial assets. Proportion of total petroleum resource value (consisting of annual value of the GPFG + present value of remaining petroleum resources) during the period 1996–2021. Data sources: GPFG quarterly and half-yearly reports and Revised National Budget for multiple years.*

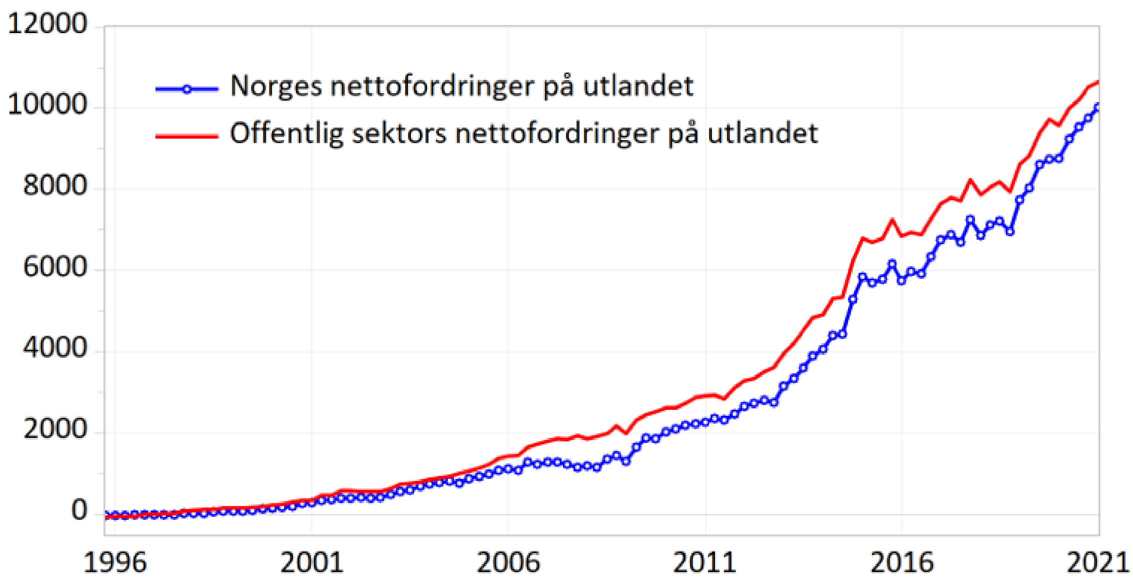


Figure 13: *Norway's net assets abroad (total and public sector) in NOK billion. The private sector as a whole possesses negative net foreign assets, which in turn reduces Norway's total net foreign assets relative to those of the public sector. Data source: Statistics Norway.*

The conversion of petroleum wealth into financial wealth over time, along with the fiscal rule governing the use of petroleum revenues, has reduced the vulnerability

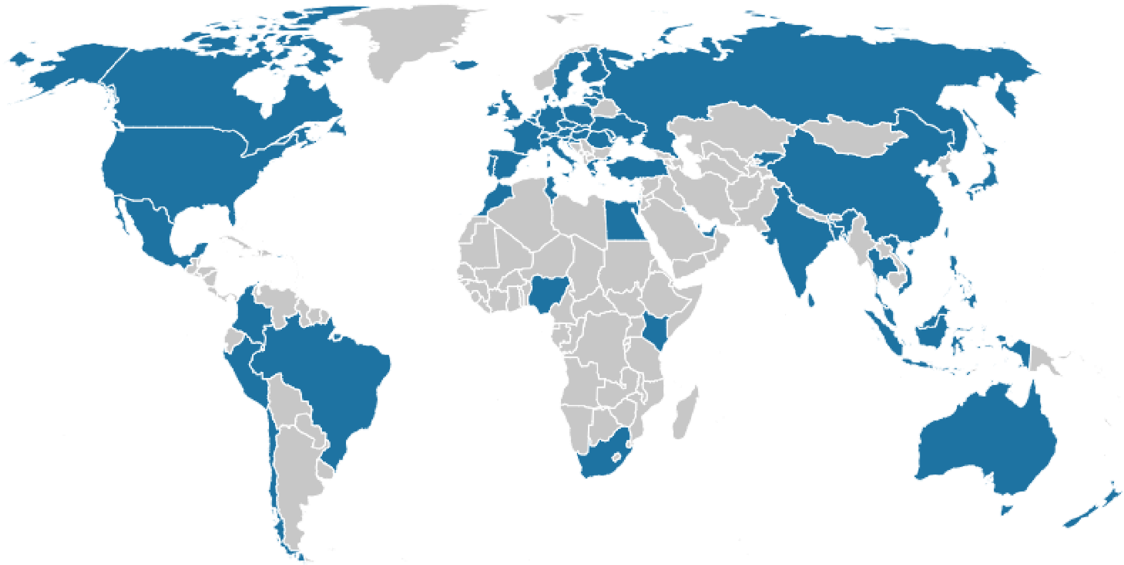


Figure 14: *GPFG investments in various countries as of the end of 2021. Figure source:* *https://www.nbim.no/en/the-fund/investments/.*

of national wealth to climate risk; cf. Skancke et al. (2021). A significantly smaller proportion of both discovered and expected (undiscovered) petroleum resources is exposed to transition risk, compared to what would have been the case if petroleum production had been directly linked to the ongoing use of petroleum revenues. This approach would have resulted in a higher level of remaining resources than current forecasts indicate; see e.g. Olje- og energidepartmentet (2021).[12] Maintaining a high pace of recovery will help reduce transition risk, as the level of potentially abandoned resources ('stranded assets') is expected to decline over time.

The financial resources represented by the GPFG are mainly invested in countries in the northern hemisphere, and are thus exposed to limited physical climate risk; see Figure 14.[13] However, they may be exposed to transition risk as climate risk-motivated changes in preferences, technology, and regulations could affect the market value of the GPFG's investments. A dynamic adjustment involving the de-weighting of investment projects with climate risk exposure and reorientation towards projects that are neutral or may benefit from the transition to more sustainable economic

[12] https://www.regjeringen.no/no/dokumenter/meld.-st.-36-20202021/id2860081/?ch=5

[13] Although many of the companies in which the GPFG is invested are global, the majority of their revenues originate from business activities in the northern hemisphere. This observation is based on regional breakdowns of the total revenues of several of the most international companies in the GPFG's equity portfolio.

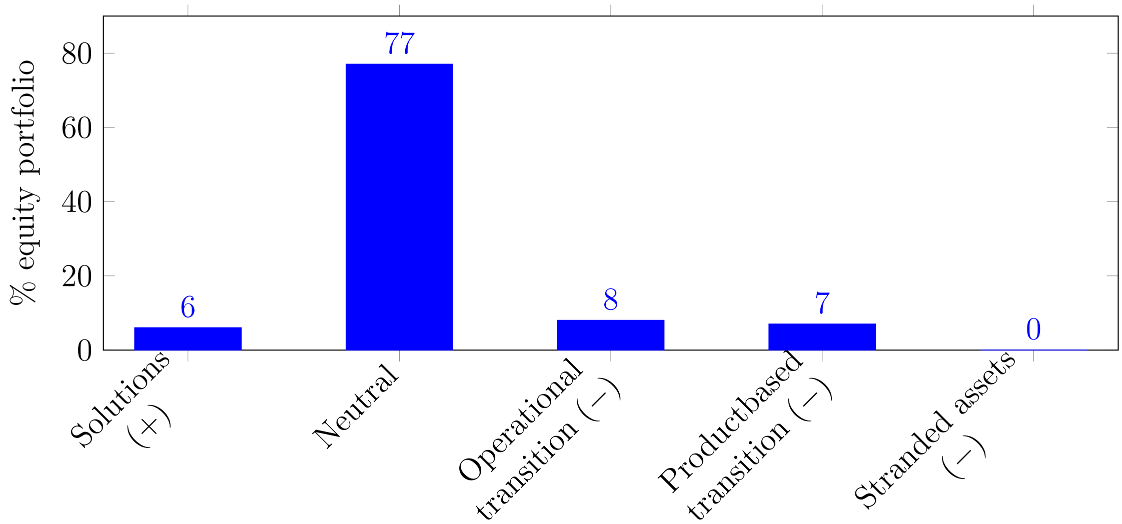


Figure 15: *GPFG equity portfolio and transition risk. Proportions of equity portfolio's market value exposed to various types of transition risk, according to the MSCI's five transition-risk categories, as of 25 March 2021. Plus and minus signs indicate whether the specified proportions in the equity portfolio are expected to increase or decrease in value as a consequences of the various transition risks. Data source: NBIM (2021).*

activity could help reduce overall transition risk.[14]

Analysis by NBIM indicates that the GPFG's financial and real investments have little negative exposure to transition risk; see NBIM (2021).[15] While bond investments are expected to have negligible exposure to transition risk due to the climate policies of issuing countries and other characteristics such as low credit risk, about 15% of equity investments are exposed to negative transition risk; see Figure 15. The GPFG's equity investments are not expected to lose significant value due to climate-motivated restrictions on the extraction or production of natural resources (stranded assets). On the contrary, 6% of the GPFG's equity investments may see an increase in value due to a shift towards climate-friendly processes and products.

Table 3 shows NBIM's estimate of the present value of the GPFG's total decline in value as a result of physical and transition risks under different scenarios for the increase in global temperature by 2080. More ambitious climate policies expressed in terms of a lower temperature rise entail a greater fall in value than less ambitious climate policies. Estimates of the transition risk-linked loss in value range from NOK 750 billion to NOK 50 billion. The physical risk-linked decrease in value is estimated

[14]For more information on the GPFG's climate action plan, see https://www.nbim.no/en/the-fund/responsible-investment/2025-climate-action-plan/.

[15]https://www.nbim.no/no/publikasjoner/brev-til-finansdepartementet/2021/klimarisiko-i-statens-pensjonsfond-utland/

Table 3: *Estimates of GPFG's transitional and physical climate risk by 2080*

Scenario	Decrease in value, %	Decrease in value, bn. NOK
Transition risk if:		
$1,5^oC$	8%	650
2^oC	4%	300
2^oC (delayed)	9%	750
3^oC	1%	50
Physical risk: RCP 8,5	4%	300

Note: Estimated decrease in value of the equity portfolio by 2080, under different scenarios, as of 31 December 2020, as a percentage and in NOK billion. The "2^oC (delayed)" scenario refers to a scenario of delayed transition and climate regulation which results in greater transition costs and loss of value in the longer term. The RCP (Representative Concentration Pathway) 8.5 scenario represents a scenario of high greenhouse gas emissions which result in the highest level of global warming according to the Intergovernmental Panel on Climate Change (IPCC) classification. Data source: NBIM (2021).

at NOK 300 billion in a relatively extreme scenario where the temperature is assumed to increase by 3 degrees. As a share of the GPFG's market value of almost NOK 11,000 billion at the end of 2020, the maximum estimated costs associated with both physical risk and transition risk equate to less than 10% (= (750 + 300)/11,000).

These point estimates of the GPFG's climate risk may be lower than the transition risk associated with the remaining petroleum resources in the event of a ban on the extraction of some or all undiscovered resources. Moreover, the macroeconomic spillover effects on Norway of the GPFG's losses, which are spread out internationally, are likely to be significantly lower than any decrease in the value of remaining petroleum resources, which will primarily have domestic spillover effects. For example, there has been little focus on the possible macroeconomic effects of relatively large fluctuations in the value of the GPFG; cf. the loss in value of almost NOK 1,637 billion in 2022, which does not appear to have had any significant spillover effects on the Norwegian economy; see e.g. Finansdepartmentet (2023) and key macroeconomic statistics for Norway.

If the GPFG faces lower transition risk than that associated with Norway's petroleum resources, the ongoing conversion of petroleum resources to financial assets in the GPFG in accordance with the fiscal policy rule will reduce transition risk for Norway over time.

It is reasonable to assume that as the GPFG grows in size and petroleum resources decline as a share of Norway's GDP and national wealth, fluctuations in the value of petroleum resources will have a diminishing effect on the krone exchange rate. Conversely, fluctuations in the market value of the GPFG may become a more significant factor influencing the krone exchange rate. Such a development could lessen the exposure of the krone exchange rate to climate risk, provided that the estimates of the GPFG's exposure to climate risk are realistic; see Figure 15. If the GPFG is less exposed to climate risk than the economies of Norway's trading partners, the Norwegian krone could appreciate in response to an increase in global climate risk.

5 Petroleum resources and transition risk

Norway is among the OECD countries that could potentially suffer a relatively large decrease in the value of their remaining petroleum resources if these cannot be fully recovered. Norway has substantial remaining petroleum resources as a result of discoveries of new oil and gas deposits over time; see Figure 16. It is estimated that approximately half of Norway's petroleum resources remain. The present values of remaining petroleum reserves in current prices over time, as calculated by the Norwegian Ministry of Finance, are shown in Figure 17. Estimates from 2021 suggest a present value of around NOK 3,300 billion. The figure also depicts the development of the GPFG's market value following the reinvestment of petroleum wealth from Norway's continental shelf, the excess returns on these investments, and the development of the krone exchange rate up to 2021.

Climate-linked decreases in the value of remaining petroleum resources may be caused by political restrictions, technological changes, or changes in consumer preferences. Political restrictions may include limitations on oil and gas exploration in areas that have not yet been opened for exploration and/or in already licensed exploration areas.[16]

[16] The following analysis of potential political restrictions should be considered purely hypothetical. According to the Norwegian government, current Norwegian petroleum policy entails "development, not discontinuation of the petroleum sector". See e.g. the Norwegian government's political platform: https://www.regjeringen.no/

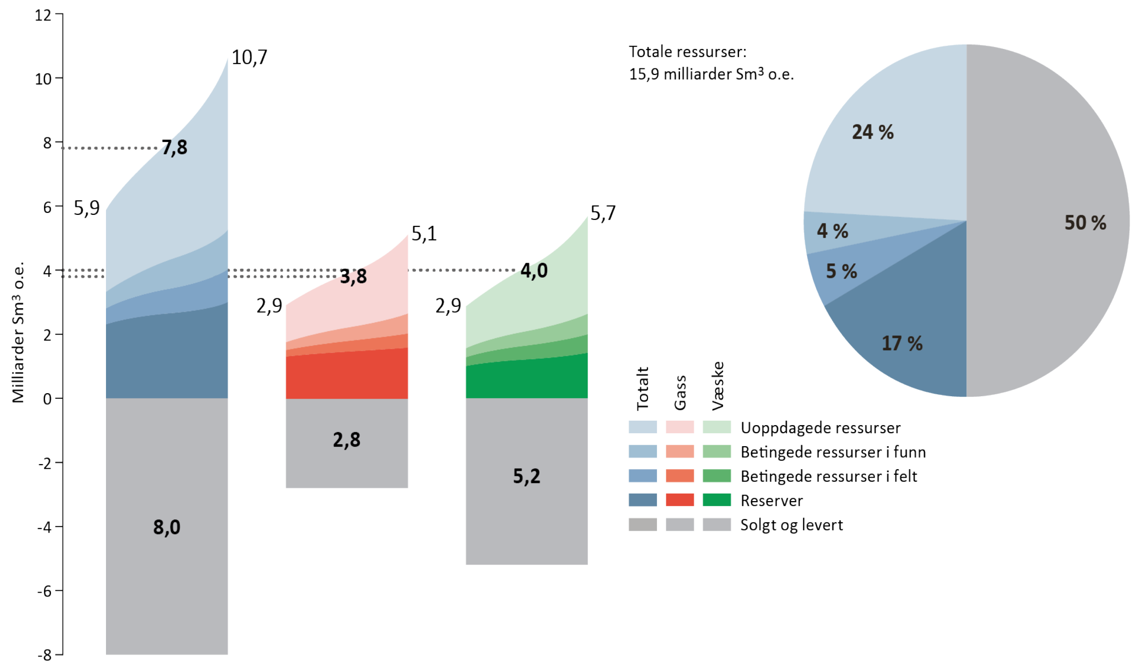


Figure 16: *Norwegian petroleum resources and associated uncertainty in estimates as of 2021. 'Betingede ressurser i felt' and 'Betingede ressurser i funn' are 'Contingent resources in fields' and 'Contingent resources in discoveries', respectively. Figure source: https://www.norskpetroleum.no/petroleumsressursene/ressursregnskap-norsk-sokkel/.*

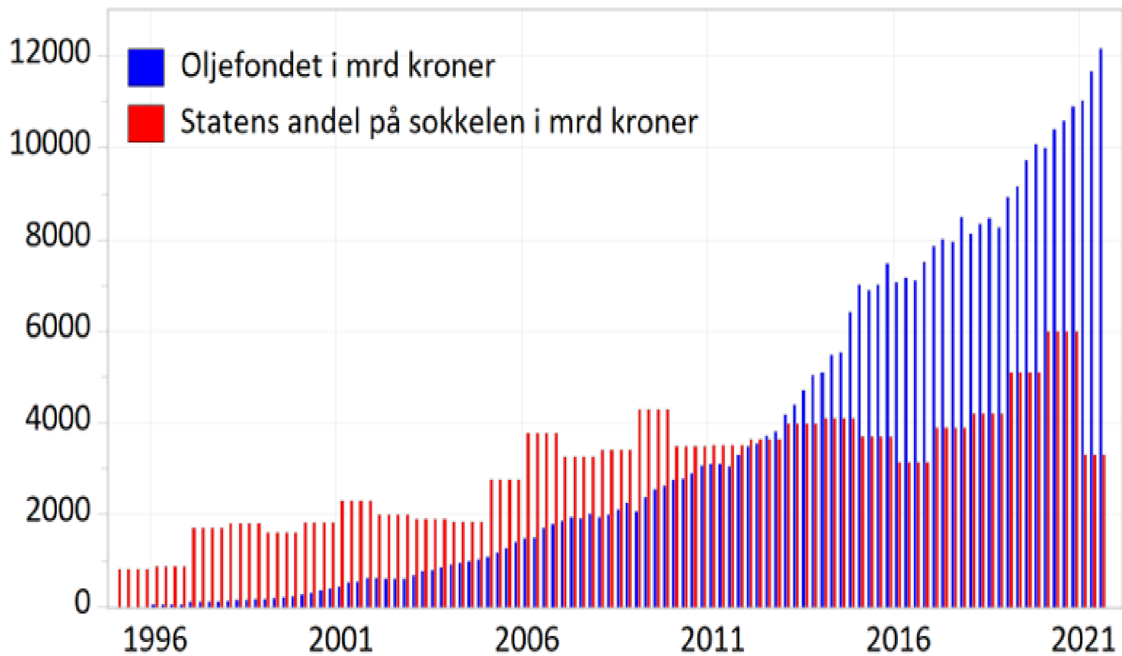


Figure 17: *Market value of the GPFG and present value of the Norwegian state's share of remaining petroleum resources as estimated in annual national budgets in the period 1996–2021, in NOK billion.*

contentassets/cb0adb6c6fee428caa81bd5b339501b0/no/pdfs/hurdalsplattformen.pdf, and the government's communication, e.g. following the UN Climate Change Conference in Dubai in 2023: https://e24.no/energi-og-klima/i/kEnAg6/

Figure 16 provides an overview of estimated petroleum resources at various stages of exploration and production. 'Reserves' shown in the darker parts of the figure represent the volume of remaining resources that are expected to be recoverable with a high degree of certainty. In contrast, the estimates labeled as 'Contingent resources in fields' and 'Contingent resources in discoveries' are less certain. These are expected resources in developed and undeveloped fields, respectively. 'Undiscovered resources', depicted in the lighter parts of the figure, are resources expected to be found in areas not yet opened for exploration. These resources are assumed to account for approximately half of the estimated total remaining resources, although their exact size remains highly uncertain.

There is considerable uncertainty regarding whether, and if so, by how much, remaining petroleum resources may fall in value or be written off. Future market conditions for petroleum are highly uncertain, influenced by factors such as technological changes, consumer preferences, and energy and climate policies. However, existing agreements and a desire for the predictability of public policy may somewhat reduce the likelihood of a politically determined production stop in fields that are already equipped with extraction infrastructure. It is also unlikely that the extraction of already discovered petroleum resources will be halted, even if the necessary infrastructure has not yet been installed; cf. Aune et al. (2020). Therefore, it can be assumed that any political restrictions on the extraction of petroleum resources will primarily affect only certain parts of the remaining petroleum resources, especially in the short term.

A simple assumption could be that political decisions leave most 'undiscovered resources' in the seabed, representing almost half of the remaining resources. Alternatively, one may assume as Aune et al. (2020) do, that only about 60 percent of 'undiscovered resources' remain unextracted, which implies that almost a quarter of the remaining resources are not extracted. A write-off ratio of between 1/4 and 1/2 of the remaining reserves would correspond to an assumed value loss ranging from NOK 792 billion to NOK 1,650 billion, based on the present value of remaining

`aasland-om-klimaavtalen-endrer-ingenting-for-norge`.

reserves in 2021 (i.e., NOK 3,300 billion). The maximum estimate of this value loss is comparable to the GPFG's loss in 2022.

The potential loss of value may be significantly higher or lower than indicated by the point estimates. Figure 16 reveals considerable uncertainty about both the total level of remaining resources and the size of 'undiscovered resources'. Moreover, future petroleum prices, production costs, and interest rates that enter the calculation of the present value of remaining reserves are highly uncertain. It is also difficult to assess the total macroeconomic costs of the spillover effects of reducing future petroleum activity; see, for example, Aune et al. (2020) and the literature on the Dutch disease, inter alia, Bjørnland et al. (2019).

Petroleum prices may be affected by any extraction restrictions and/or taxes; see Carlin et al. (2022). A relatively large increase in the price of petroleum resources, resulting from such policy actions, could potentially more than offset the decline in the value of remaining petroleum resources; see Figure 18. However, a price effect is conditional on more or less internationally coordinated production restrictions or tax increases. Given the considerable size of remaining petroleum resources globally, measures that only affect Norwegian petroleum production may have little effect on petroleum prices.[17]

Technological changes, energy efficiency measures, or shifts in consumer preferences may, through lower demand for petroleum resources, lead to both a fall in prices and a decline in production; see Figure 19. Such shifts may reduce the value of remaining reserves more than politically determined production cuts, which may have an uncertain effect. However, it is not obvious that Norway will cut production even if global petroleum demand and production fall overall.

A possible fall in the value of remaining petroleum resources in the event of negative shifts in demand will also depend on how petroleum producers respond to such shifts. Asheim et al. (2019) propose cooperation between producer countries with the aim of moderating any fall in prices by regulating the decline in production.

[17] See e.g. OPEC Annual Statistical Bulletin (2022), https://www.opec.org/opec_web/en/publications/202.htm and the overview on the website https://howmuch.net/articles/worlds-biggest-crude-oil-reserves-by-country.

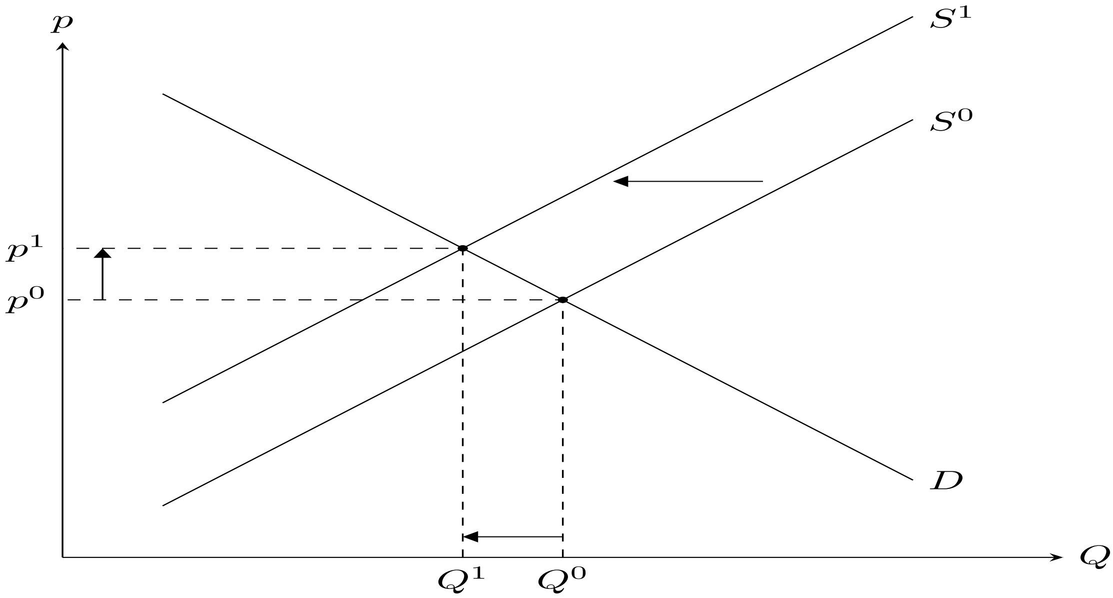


Figure 18: *Global oil market where supply-side factors leads to lower oil production (Q) and higher oil prices (p).*

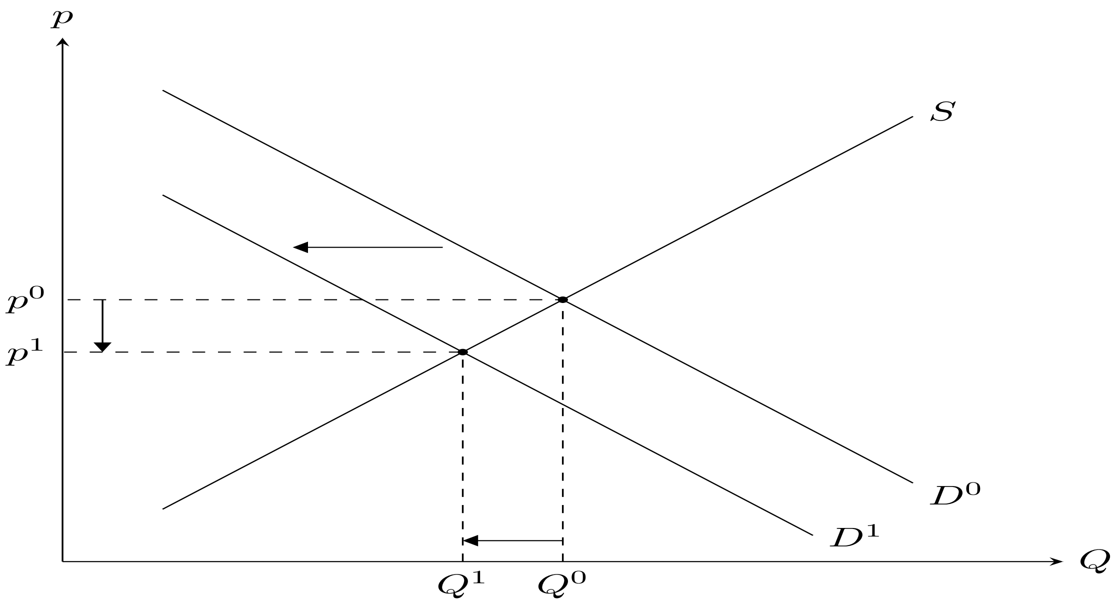


Figure 19: *Global oil market where demand-reducing shifts in regulations and/or consumer preferences lead to lower prices and production.*

In this scenario, total production would be reduced to support the achievement of climate goals, but the producer countries' loss of income would be smaller than in the event of a purely demand-driven production decline; see Figure 20.

Time lags in the decline of demand for petroleum, due to inertia in consumer behaviour and sluggishness in technological and political processes, also contribute to reducing the transition risk associated with remaining petroleum resources. Figure 21 points to a decline in the value of remaining petroleum resources over time, con-

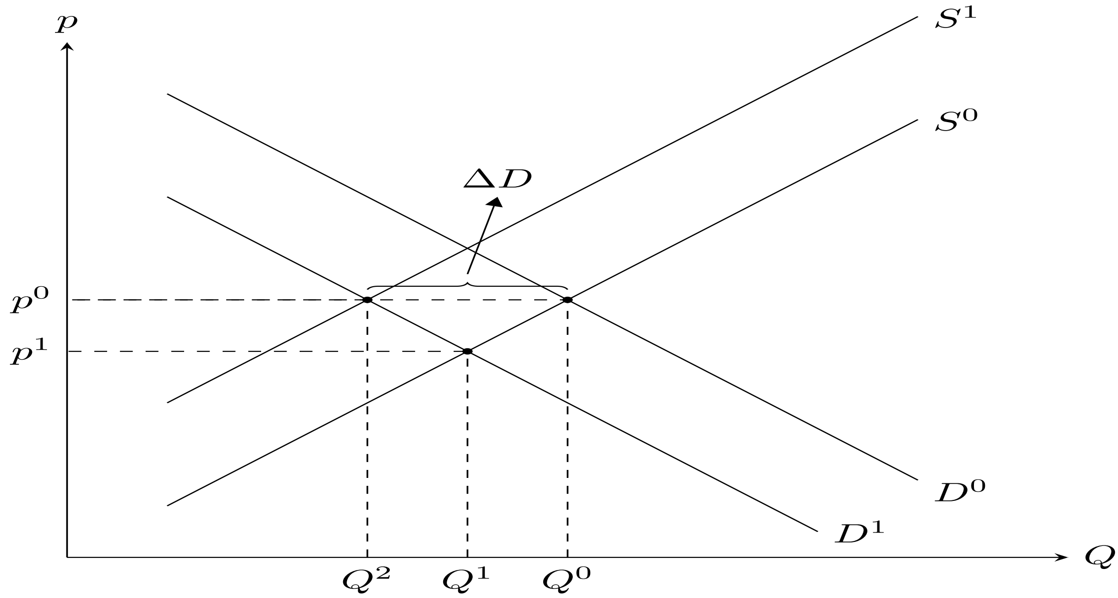


Figure 20: *Global oil market where supply constraints in response to lower demand amplify the decline in production while avoiding a fall in oil prices; cf. Asheim et al. (2019).*

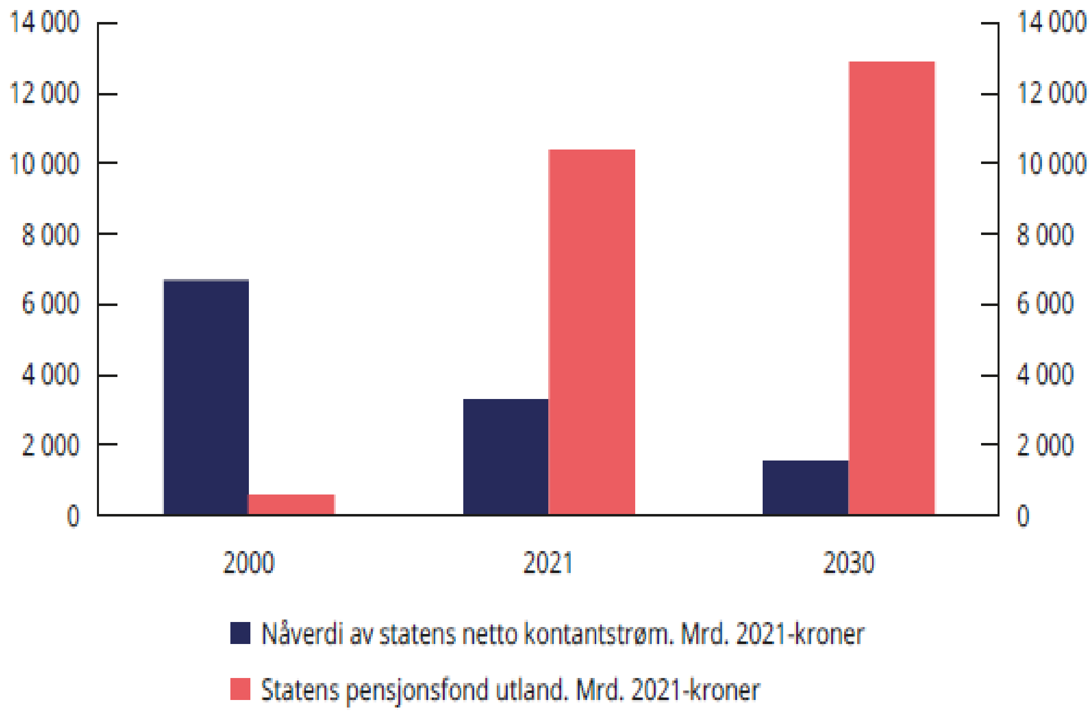


Figure 21: *Projected conversion of petroleum wealth to financial assets in the period 2000–2030. Figure source: Finansdepartmentet (2021).*

sistent with production projections under current climate and petroleum policies. In the absence of major new petroleum discoveries, the value of remaining petroleum resources may become relatively small over the next decade, especially when compared to other components of Norway's national wealth, such as the GPFG.

Even a large fall in the value of Norway's petroleum resources due to transition risk does not necessarily entail a permanent weakening of the external balance and a decline in the exchange rate. As shown above, these constitute one of several components of Norway's national wealth which may be impacted in different ways by climate risk. Differences between countries in terms of the impact of climate risk on different components of national wealth may influence the development of exchange rates between them. In addition, differences between countries related to their management of climate risk may contribute to comparative advantages in the tradable sectors. The next chapter discusses the scope and pace of the green transition and its potential impact on countries' comparative advantages relative to each other.

6 Advantages to a faster green transition?

Way et al. (2022) have estimated that replacing carbon-intensive energy sources with renewable energy sources could reduce global energy costs by several thousand billion USD. They assume that prices of renewable energy sources will continue to fall relative to oil and gas prices, and that their adoption will proceed at a pace similar to historical trends. Additionally, the savings from carbon tax costs through the adoption of renewable technologies could provide another source of comparative advantage over time, particularly if carbon taxes become more prevalent internationally and more accurately reflect the overall social and economic costs associated with carbon emissions; see Adrian et al. (2022).[18]

Countries that adopt renewable energy sources more extensively and rapidly than others may consequently realise lower energy costs per unit compared to other countries. This also implies that exporters of carbon-intensive energy sources, who also produce or utilise renewable energy, can partly or wholly compensate for potential losses. These losses may be related to extraction restrictions on their carbon-intensive energy resources, lower profits from extractions compared to pre-restriction

[18] Adrian et al. (2022) estimate that replacing coal use with renewable energy could result in global net savings of at least USD 85,000 billion in saved carbon taxes.

levels, or other climate risk-related changes in technology and consumer preferences.

Way et al. (2022) have estimated total savings linked to varying paces of adaptation to renewable energy sources. Their estimates suggest that the total global savings could reach as much as USD 12,000 billion in a scenario of a fast transition from carbon-intensive energy sources to renewable ones. Therefore, the total cost savings could far outweigh the wealth losses due to write-offs on carbon-intensive energy sources. As noted above, Semieniuk et al. (2022) have estimated these losses at approximately USD 1,000 billion, which is about one-tenth of the potential cost savings from a fast transition to renewable energy sources.

There are significant differences between countries regarding the pace of expansion of renewable energy production capacity and in the adoption of climate-friendly goods and services. The pace of expansion is supported by various public support schemes, taxes, subsidies, and regulations.[19] Production capacity is growing across countries and regions; see International Energy Agency (2023). So is the demand for climate-friendly products.

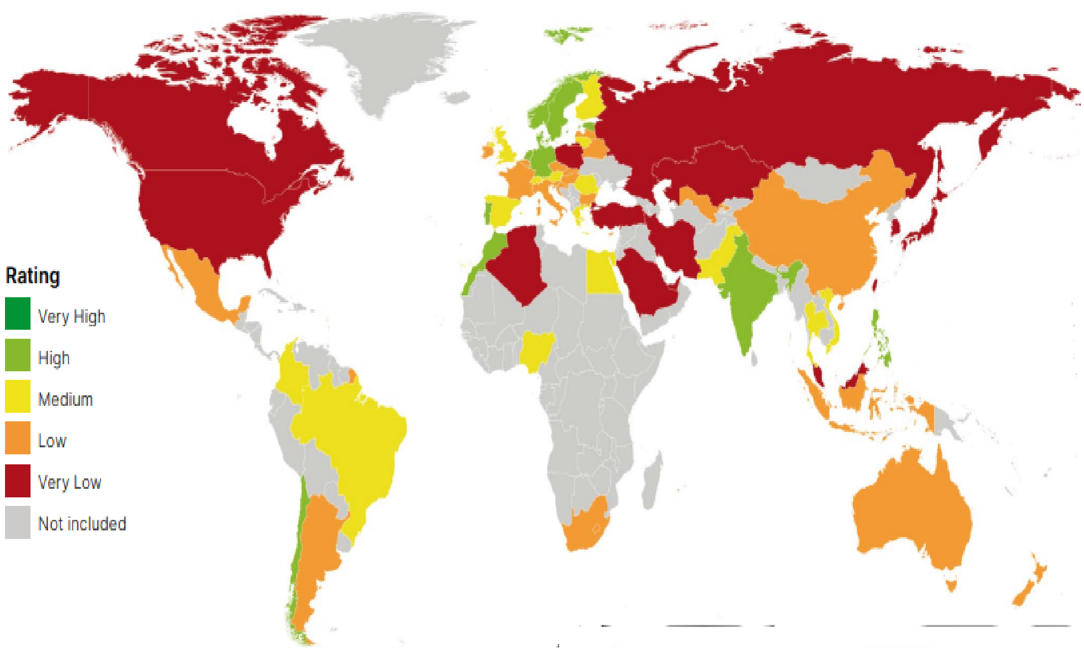


Figure 22: *Different countries' climate-supporting measures and contributions. Figure source:* *https://ccpi.org/wp-content/uploads/CCPI-2024-Results.pdf*.

[19]One example is Norway's offshore wind initiative, which could eventually help to double the country's total power production: https://www.regjeringen.no/no/aktuelt/historisk-satsing-pa-havvind/id2930618/.

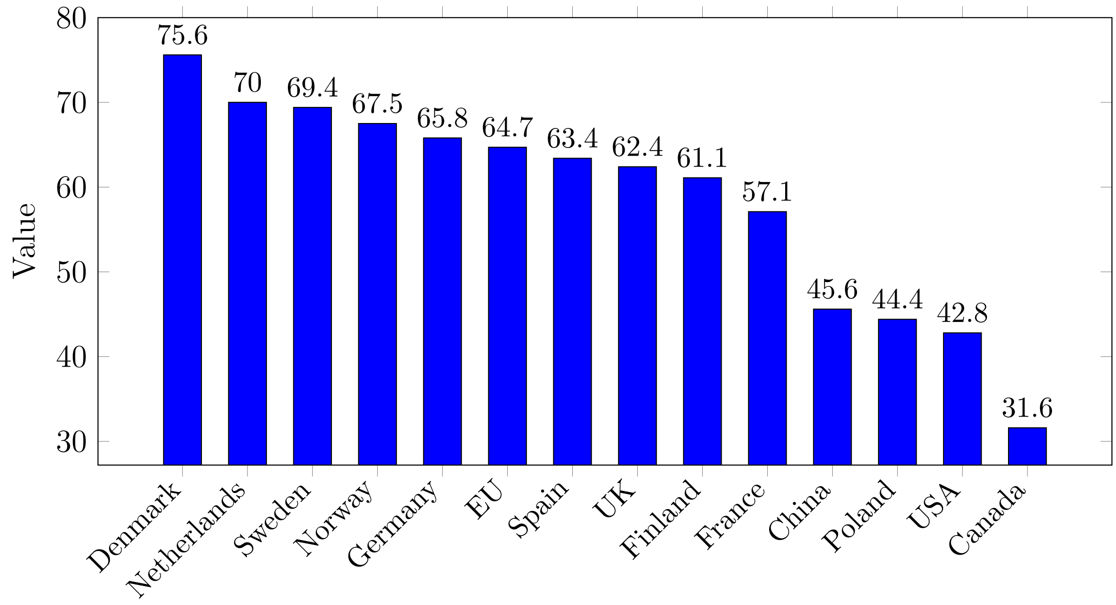


Figure 23: *Green transition index values (Climate Change Performance Index, CCPI) for Norway and its main trading partners. The evaluated factors include greenhouse gas emissions, production and consumption of renewable energy and climate policy. The CCPI is based on a standardised framework and aims to provide an independent assessment of the level of transition in the different evaluated countries – currently totalling 63 countries as well as the EU. For further information and data: https://ccpi.org/wp-content/uploads/CCPI-2024-Results.pdf.*

Possible cost savings linked to transitioning to renewable energy sources could give countries which adopt such sources earlier than other countries a comparative advantage in the production of goods and services. Material differences between countries in terms of regulations and their effectiveness in accelerating the transition to renewable energy sources could enable some countries to outpace others for extended periods of time.

Figure 22 indicates how quickly different countries and regions are transitioning to climate-friendly economies, according to the Climate Change Performance Index.[20] Figure 23 shows the indicator values for Norway and its main trading partners. The figures suggest that Norway is transitioning faster than almost all of its trading partners and most other countries in the world. If this relatively rapid transition results in lower per-unit production costs for goods and services in Norway compared to those of its trading partners, it may, in isolation, contribute to a stronger krone exchange rate.

[20] See https://ccpi.org/ for more information.

The analysis in this and earlier chapters has identified several factors that may contribute to increased climate risk coinciding with a stronger krone exchange rate. However, a number of studies have argued for a loss in the value of petroleum resources due to climate risk and suggested this as a possible explanation for the depreciation of the Norwegian krone in recent years; see Kapfhammer et al. (2020) and Benedictow and Hammersland (2023). The next chapter examines empirically whether there has been a correlation between climate risk and the krone exchange rate over the past decade.

7 Has climate risk affected the krone exchange rate so far?

Commonly used empirical models of the krone exchange rate have not been able to fully explain the krone's depreciation in several of the years following the fall in oil prices in 2014/2015. This period partially overlaps with the signing of the Paris Agreement in December 2015. Kapfhammer et al. (2020), among others, have argued that an increase in transition risk, prompted by a heightened focus on climate risk and a potential write-down of petroleum reserves, has led to a weakening of the exchange rates of petroleum-producing countries, including Norway.[21]

Akram (2020), on the other hand, has shown that developments in the exchange rates of countries like Norway and Canada can largely be explained by employing conventional variables such as interest rate differentials, risk indicators, and oil prices, provided that one allows for shock-dependent effects of oil prices on exchange rates. The following analysis also suggests that climate risk does not contribute to explaining the krone exchange rate beyond what can be explained by somewhat expanded models with conventional explanatory variables.

[21] The actual fall in oil prices in 2014/2015 is usually attributed to significant shale oil production in the US, sustained high oil supply from OPEC countries, and a recession-induced reduction in global oil demand. For further analysis of the oil price decline in 2014/2015, see Arezki and Blanchard (2014): https://www.imf.org/en/Blogs/Articles/2014/12/22/seven-questions-about-the-recent-oil-price-slump and Kilian (2015): https://cepr.org/voxeu/columns/why-did-price-oil-fall-after-june-2014.

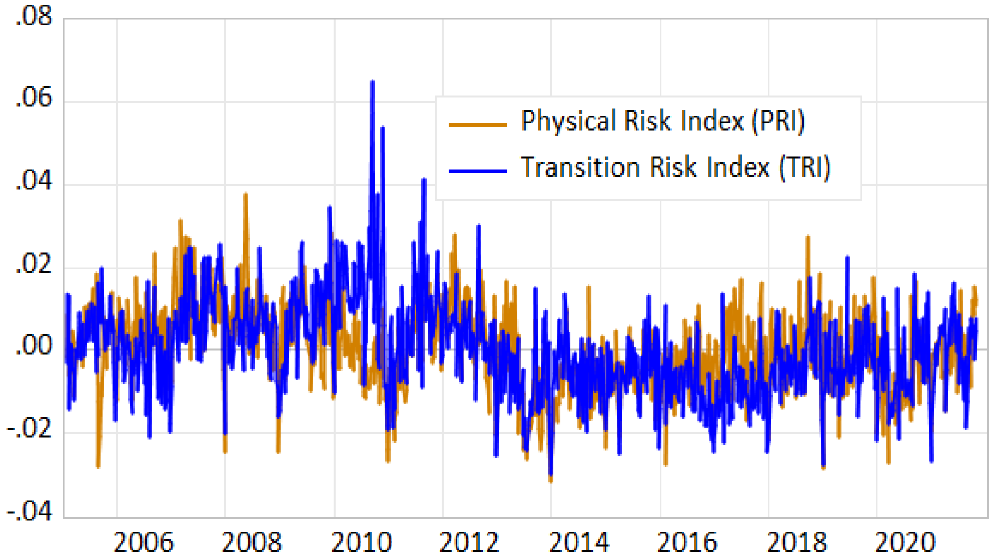


Figure 24: *Indicator values (weekly frequency) for physical risk and transition risk over the time period January 2005–October 2021. These are based on daily data from the authors of Bua et al. (2022).*

It is not obvious how climate risk should be measured and how one should distinguish between physical risk and transition risk in analyses of financial variables where prices are assumed to incorporate available information. Moreover, many measures of physical and transition risks depend on structural factors that generally change too slowly to explain short-term fluctuations in financial variables; cf. the physical climate risk indicators discussed in Chapter 2.

A recently suggested approach to incorporating new information about climate risk involves basing climate risk indicators on the daily volume of news articles that directly or indirectly address climate risk in the form of physical or transition risk. Kapfhammer et al. (2020) have represented transition risk using an indicator based on explicit or implicit mentions of transition risk in the Dow Jones news archive from 2001 to 2019. In a more recent study, Bua et al. (2022) have developed indicators of both physical risk and transition risk based on climate risk-related news published by Reuters News from January 2005 to October 2021.

Figure 24 displays weekly values of the latter indicators for physical and transition risk. The indicators are constructed to reflect climate risk news beyond what is covered in the ongoing scope of news on climate-related risks and concerns. The fig-

Table 4: *Model of nominal import-weighted exchange rate I44, excluding climate risk*

Dependent Variable: LOG(I44)
Method: Fully Modified Least Squares (FMOLS)
Sample (adjusted): 30/12/2009 27/10/2021
Included observations: 618 after adjustments
Cointegrating equation deterministics: C

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.266	0.045	95.285	0.0000
$i^s - i^{f,s}$	-0.028	0.009	-3.136	0.0018
$\{(i^L - i^s) - (i^{f,L} - i^{f,s})\}$	-0.077	0.013	-5.901	0.0000
oilp^{Dem}	0.001	0.015	0.075	0.9400
oilp^{Sup}	-0.178	0.006	-28.671	0.0000
oilp^{Res}	-0.159	0.026	-6.202	0.0000
vix	0.032	0.007	4.906	0.0000
R-squared	0.967	Mean dependent var		4.597
Adjusted R-squared	0.967	S.D. dependent var		0.095
S.E. of regression	0.017	Sum squared resid		0.186
Long-run variance	0.001			

Note: $i^s - i^{f,s}$ is the 12-month nominal swap rate differential between Norway and its trading partners, while $\{(i^L - i^s) - (i^{f,L} - i^{f,s})\}$ represents the difference between the slopes of the interest-rate curves for Norway and its trading partners. The long-term nominal interest rates (i^L og $i^{f,L}$) are 10-year swap rates. The decomposition of the log of the Brent Blend crude oil price into demand side-driven, supply side-driven, and an unexplained term has been taken from the New York Fed's *Oil Dynamics Report*; see e.g. https://www.newyorkfed.org/medialibrary/media/research/policy/oil_decomposition/oil-decomp_2021-1129.pdf. Finally, log of the VIX index represents general market uncertainty. See Akram (2020) for further details of the variables and the model specification.

ure does not reveal a clear upward tendency in these indicators either over the entire time period or since 2014/2015, which could have correlated with any unexplained weakening of the krone exchange rate, particularly in the last decade.

In the following, we investigate in more detail whether the indicators for physical and transition risks can help explain fluctuations in the nominal import-weighted exchange rate for Norway (I44) that are not accounted for by commonly used explanatory variables. Table 4 presents an estimated model of the logarithm of I44, where we include the 12-month interest rate differential relative to trading partners, the difference between the slopes of the yield curves relative to trading partners (expressed as differences between 10-year and 12-month interest rate differentials), and the oil price decomposed into demand- and supply-driven factors as well as factors

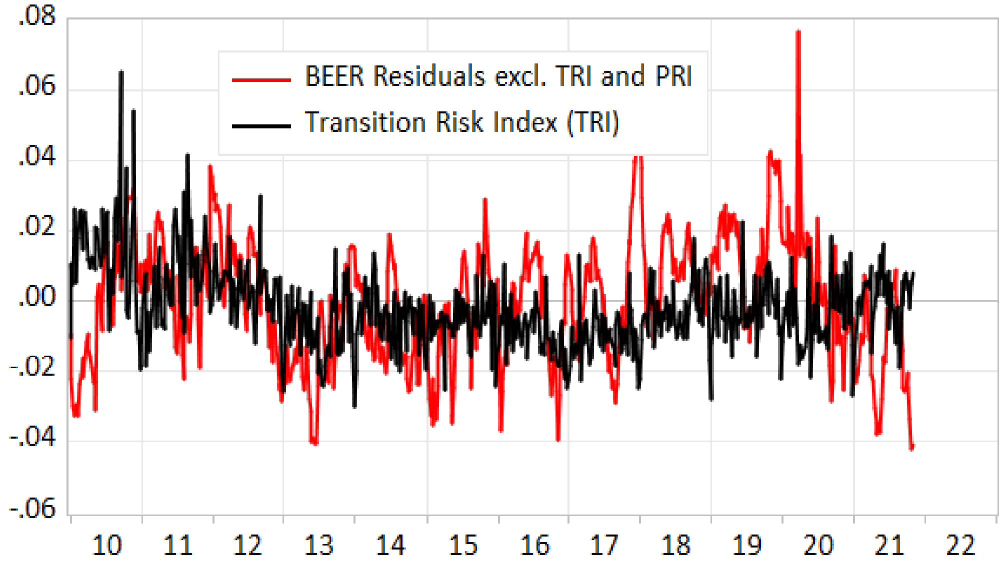


Figure 25: *Indicator values for transition risk and unexplained variation in the nominal effective exchange rate I44 (in red) in the period January 2010–October 2021; weekly data.*

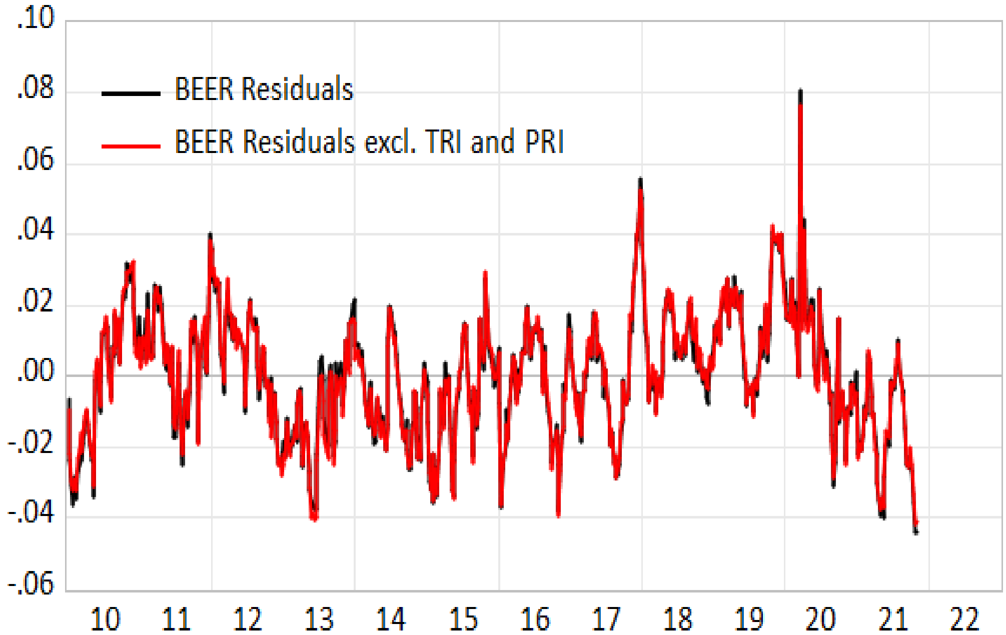


Figure 26: *Residuals from the model in Table 4, where PRI and TRI are not included (in black), and from the model in Table 5, where these indicators are included. The estimation period is January 2010–October 2021; weekly data.*

that are difficult to place in these two categories.[22] The series for the various components of the oil price are sourced from the New York Fed's *Oil Dynamics Report*,

[22]While supply-driven oil prices (oilp^{Sup}) can represent oil price changes linked to climate risk-motivated production restrictions, this is not the case for demand-driven oil prices (oilp^{Dem}). The latter refers to oil prices driven by demand associated with global economic development, not to climate risk-motivated demand changes as discussed in Chapter 5.

Table 5: *Model for nominal import-weighted exchange rate I44, with climate risk*

Dependent Variable: LOG(I44)
Method: Fully Modified Least Squares (FMOLS)
Sample (adjusted): 30/12/2009 27/10/2021
Included observations: 618 after adjustments
Cointegrating equation deterministics: C

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.264	0.045	95.810	0.000
$i^s - i^{f,s}$	-0.030	0.009	-3.368	0.001
$\{(i^L - i^s) - (i^{f,L} - i^{f,s})\}$	-0.080	0.013	-5.967	0.000
oilp^{Dem}	0.004	0.015	0.232	0.817
oilp^{Sup}	-0.178	0.006	-28.742	0.000
oilp^{Res}	-0.163	0.026	-6.222	0.000
vix	0.032	0.007	4.777	0.000
TRI	0.121	0.176	0.687	0.492
PRI	0.132	0.189	0.702	0.483
R-squared	0.967	Mean dependent var		4.597
Adjusted R-squared	0.966	S.D. dependent var		0.095
S.E. of regression	0.017	Sum squared resid		0.186
Long-run variance	0.001			

Note: The TRI and PRI variables indicate transition risk and physical risk, respectively. These variables are described in greater detail in Bua et al. (2022). See Table 4 for a more detailed explanation of the other variables in this model.

while the decomposition is further explained in Groen et al. (2013).[23] The model also includes the log of the VIX index to account for general market uncertainty. We estimate the model on weekly data over the time period January 2010 to the end of October 2021, when the time series for the climate risk indicators end.

Figure 25 displays the residuals from the model in Table 4, alongside the values of the transition risk indicator (TRI) over the estimation period. These residuals represent the log values of I44 that are not explained by the model, with positive values indicating unexplained depreciation of the exchange rate. There does not appear to be a clear correlation between these unexplained changes in the exchange rate and the fluctuations in TRI throughout the estimation period. A similar observation was made with the physical risk indicator (PRI).

Table 5 presents an estimated model of the nominal import-weighted exchange rate, which, in addition to conventional explanatory variables, includes indicators

[23] See https://www.newyorkfed.org/research/policy/oil_price_dynamics_report for data and relevant references.

for both physical and transition risks. The table shows that there is no statistically significant relationship between the climate risk indicators, TRI and PRI, and the exchange rate.

Figure 26 displays the residuals from both models. As shown, the residuals are virtually identical throughout the estimation period. This suggests that the model which includes climate risk indicators presented in Table 5 does not have significant explanatory power over and above the model in Table 4, which does not include climate risk indicators.

8 Summary – a stronger krone?

The krone exchange rate, a relative price, depends on various factors, including expectations about the future development of the Norwegian economy relative to the economies of Norway's trading partners. Differences in exposure to climate risk between Norway and its trading partners, and how well Norway manages climate risk compared to its trading partners, may all affect the development of the krone exchange rate.

Table 6: *Factors which indicate a stronger (+) or weaker (-) krone*

Factor	NOK value	Reference
Physical risk relatively lower	+	Fig. 2
Transition risk relatively lower	+	Fig. 1
Capacity to manage relatively higher	+	Fig. 5 and 11
Labour productivity less exposed	+	Fig. 6
Diversification of net foreign assets	+	Fig. 14 and 15
Risk of stranded assets	−	Fig. 16
Faster transition than in trading partners	+	Fig. 22 and 23

Note: The table shows how Norway's position relative to that of its trading partners, as measured by various climate risk-related parameters, may imply a stronger (+) or weaker (-) krone exchange rate going forward. Reference is also made to selected figures indicating Norway's relative position.

Table 6 summarises the exposure and response capacity of the Norwegian economy related to climate risk, compared to the exposure and response capacity of Norway's trading partners. Lower relative exposure, higher response capacity and less unfavourable effects imply a stronger krone exchange rate, whereas the opposite conditions suggest potential depreciation. The table also references evidence presented in various figures, which support the arguments in the first column.

The table shows that climate risk does not have an unambiguous impact on the krone exchange rate, and there are several factors suggesting that the krone exchange rate could strengthen as a result of climate risk. On the one hand, the potential loss of value from a partial non-extraction of petroleum resources could weaken the krone exchange rate. On the other hand, factors such as Norway's geographical location, strong economic and governance conditions, well-diversified financial assets, and rapid pace of transition to the use of renewable energy resources could contribute to an appreciation of the Norwegian krone in response to both physical and transition risks.

Our empirical analysis of the relationship between different types of climate risk and the krone exchange rate, based on historical data, does not indicate a correlation in either direction. A longer sample incorporating more recent data might yield different results, but based on the current findings, one may conclude that the depreciation of the krone over the past decade should not be attributed to climate risk.

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