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Climate change and the role of central banks

Fiscal policy is key to meeting global climate goals

The climate goals are best achieved by a combination of tax incentives and green investments. Tax incentives are most efficient if they are announced in advance for a time horizon that is relevant to investment decisions.

Read more

Central banks are well in the process of adapting

Climate change and the transition to a green economy can challenge central banks' objectives of price and financial stability. Central banks have a task in adapting to the new challenges. By doing so, they indirectly support the transition.

Read more

Climate is a new area for central banks

Central banks' role in the transition to a green economy is developing. The outcome of this development will vary across central banks, depending on their respective mandates and other country-specific circumstances.

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Climate change

Climate change is impacting society already today and will have further consequences in the future. A successful green transition will require unprecedented efforts, both in Denmark and abroad.

As a case in point, climate change and the transition to a greener economy will impact corporate earnings and economic activity. This may compromise price and financial stability in Denmark, which it is Danmarks Nationalbank's objective to ensure. It is therefore essential that Danmarks Nationalbank increases its knowledge of how, and by how much, the climate challenges will impact various parts of the economy.

Against this backdrop, Danmarks Nationalbank will focus on climate challenges in a series of publications.

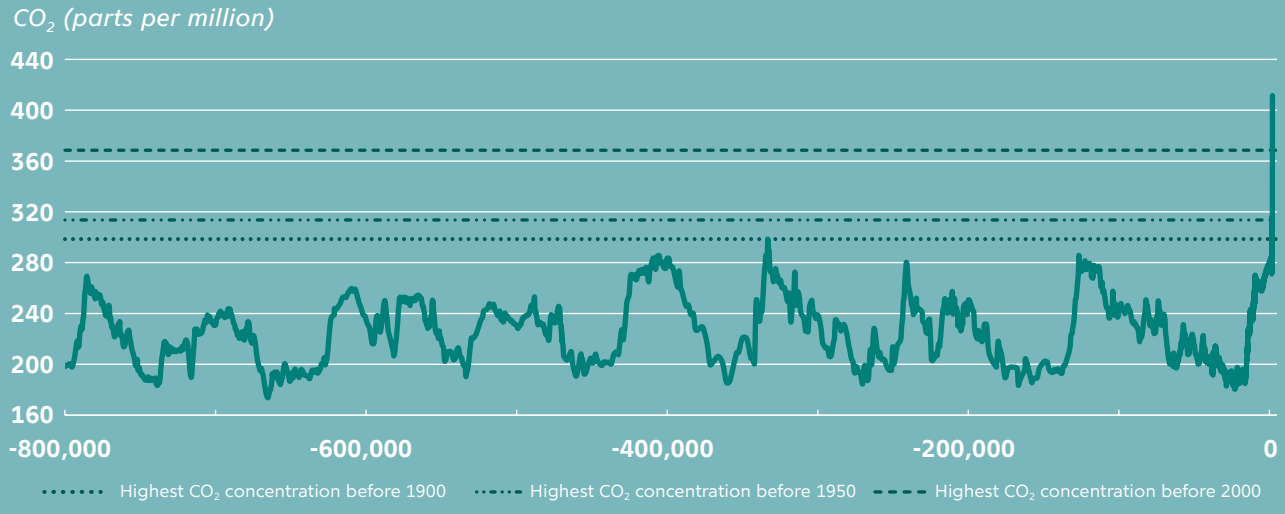
ABOUT THIS ANALYSIS

For the first time, Danmarks Nationalbank takes an overall stand on its role in relation to climate change and the transition to a green economy. Climate change and the transition may pose challenges to the objectives of price and financial stability. Central banks have a task in adapting to the new challenges.

CO_2 concentration in the atmosphere

800,000 BCE to 2019 ACE

The chart shows the number of carbon dioxide molecules per million molecules of dry air.



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Source: National Oceanic and Atmospheric Administration (until 1957) and National Aeronautics and Space Administration (from 1958).

Introduction

In recent years, many central banks have begun examining the economic consequences of climate change and the transition to a green economy. The efforts reflect a growing recognition that climate change and the transition may pose challenges to the objectives of price and financial stability.[1] It is typically the purpose of central banks to ensure these objectives. Central banks thus have an important task in adapting to the consequences of climate change and the transition.

This analysis first reviews recommendations from the economic literature on how best to achieve the global climate goals. The analysis then provides an overview of the impact of climate change and the transition on the economy and the financial system. Finally, the analysis takes stock of central banks' climate efforts and the ongoing discussions on central banks' role in relation to the climate.

How are the climate goals best achieved?

Since the Industrial Revolution began around 250 years ago, the systematic burning of fossil fuels and the intensified cultivation of land have increased greenhouse gas emissions. This has led to an accumulation of greenhouse gases in the atmosphere.[2] Today, there is scientific agreement that this accumulation causes global warming on account of the greenhouse effect.[3] If the emission continues, the heightened concentration of greenhouse gases is likely to result in an average global temperature increase of 3-6°C in 2100 relative to pre-industrial levels.[4]

The international efforts to halt greenhouse gas emissions are anchored in the Paris Agreement from 2015. The agreement aims to limit the long-term global temperature increase to below 1.5-2°C compared to pre-industrial levels.[5] Meeting the 1.5°C goal requires that global net emissions cease by 2050.[6]

Private companies are already taking important steps towards climate neutrality

Private companies worldwide are already reducing their greenhouse gas emissions. Non-financial companies, for example, reduce their emissions through investments in energy savings, as well as through research in and development of green technologies.[7]

Financial companies also increasingly contribute to the transition. For instance, this happens when portfolio managers receive explicit mandates to invest in green assets.[8] At the same time, credit institutions (i.e. banks and mortgage credit institutions) increasingly issue green loans and bonds.[9] Industry associations also prepare principles and methods for measuring and reporting the financial sector's

1 The IMF (2020, Chapter 3) estimate that global GDP may be 5-10 per cent lower by the middle of the century and 15-30 percent lower by the end of the century relative to a situation with a stable climate towards the end of the century.

2 Greenhouse gases are atmospheric gases that cause the greenhouse effect by capturing part of the thermal radiation from the Earth and returning it towards Earth. Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases are the primary gases associated with climate change, see IPCC (2014).

3 The UN *Intergovernmental Panel on Climate Change* (IPCC) provides regular scientific assessments on climate change and options for adaptation and mitigation. Human-induced warming reached about 1°C above pre-industrial levels in 2017, i.e. an increase of 0.2°C per decade, see IPCC (2018).

4 IPCC (2014), IMF (2020, Chapter 3).

5 United Nations (2015).

6 IPCC (2018).

7 Greenhouse Gas Protocol (2004) lays down a set of international standards for measuring and reporting companies' greenhouse gas footprints.

8 Danmarks Nationalbank (2021).

9 The annual issuance of green loans and bonds from non-government issuers has grown from 33 billion dollars in 2014 to 238 billion dollars in 2020, see Climate Bonds Initiative (2021).

financed greenhouse gas footprint from lending and investments.[10]

Market forces are not sufficient to ensure a transition

The current profit incentives to halt greenhouse gas emissions cannot stand alone. Projections show that the world is a long way from meeting the goal of climate neutrality by 2050.[11] This also applies to Denmark, which is some way from meeting the goals laid down in the Danish Climate Act to reduce greenhouse gas emissions by 70 per cent by 2030, compared to the 1990 level, and to achieve climate neutrality by 2050.[12]

The reason for the gap between estimated future emissions and the climate goals is that households and companies do not fully pay for the global costs in the form of climate change when they decide the volume of their emissions. This type of market failure is known as an *externality* in economic literature. The externality implies that global emissions are above the globally optimum level when balancing the pros and cons of emissions on a global scale.[13]

For this reason, it is unlikely that, in the future, private profit incentives alone can ensure a transition in accordance with the Paris Agreement. Consequently, policy measures are necessary.

An important purpose of policy measures is to bring about a level playing field for companies. This is to prevent another type of market failure, namely *free-rider problems*. With free-rider problems, companies that reduce their emissions risk being ousted by companies that do not reduce their emissions. The free-rider problem is solved by ensuring that it is worthwhile for all companies to transition, while retaining healthy competition.[14]

Inclusion, investment and information

A growing economic literature examines which tools are most cost-effective in meeting the climate goals.[15] The policy measures to ensure the transition come in three forms: *inclusion*, *investment* and *information*.[16] The measures complement each other. This means that if, say, a measure is omitted, the remaining measures will not have full impact. It is therefore important to have the right climate policy mix, i.e. to combine different of policies to achieve a desired outcome.

Ideally, the policy measures should be global, as it is immaterial to the greenhouse effect where in the world greenhouse gases are emitted. However, there are no current prospects of an agreement on effective global solutions. Regional and national measures are therefore necessary.

Climate clubs are an example of regional measures. A climate club is a coalition of countries that introduce common measures to transition. At the same time, the club can introduce common import tariffs on countries that do not lower their emissions. The tariffs are sometimes referred to as a *carbon border adjustment mechanism*. An aim of the tariffs is to alleviate negative impacts on competitiveness resulting from the coalition's climate action. This encourages countries outside the coalition to take climate action and join the coalition.[17]

10 A set of international standards for measuring and reporting the financed greenhouse gas footprint follows from the recommendations from the *Financial Stability Board*'s *Task Force on Climate-related Financial Disclosures*, see TCFD (2017). A similar set of standards has been prepared by *Finance Denmark*, see Finans Danmark (2020).

11 IPCC (2014), IMF (2020, Chapter 3).

12 Danish Council on Climate Change (2020, 2021).

13 Solow (1971).

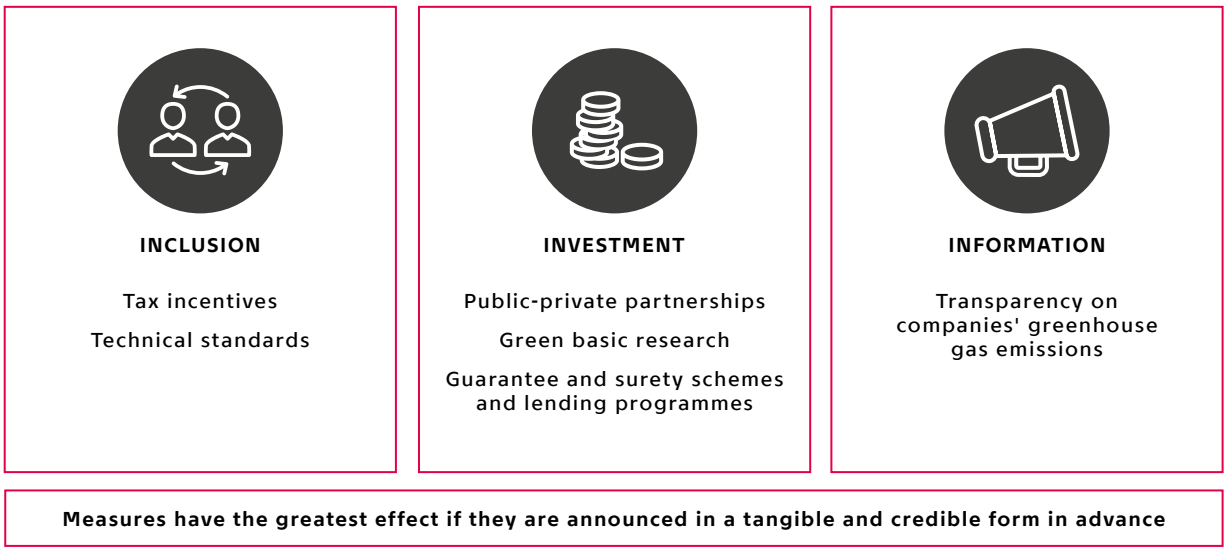
14 In the short term, free-rider problems also apply across countries. Countries that do not reduce their emissions can achieve competitive advantages at the expense of green countries. Conversely, in the long term, there may be competitive advantages for a country to lead the way in the transition, as this allows the country to specialise in green technologies ahead of its competitors.

15 See Krogstrup and Oman (2019) and Van der Ploeg (2020) for a review of the literature.

16 The concepts *inclusion*, *investment* and *information* are inspired by ECB President Christine Lagarde's speech at *BIS Innovation Summit 2021*.

17 Germany's Minister of Finance Olaf Scholz has proposed a climate club, see Scholz (2021). See also Nordhaus (2015) and OECD (2020b).

Key policy tools in a transition to a green economy Chart 1



Inclusion:
Uniform greenhouse gas taxation is best

Inclusion means that the costs to society of greenhouse gas emissions and climate change are included in the price of emitting greenhouse gases. The relative price of the emissions accordingly increases. The purpose of inclusion is to make it more expensive to produce and purchase emissions-intensive goods and services. This supports a behavioural change towards lower emissions.[18]

Inclusion can be ensured in different ways. Economic theory points to tax incentives as the ideal tools. A greenhouse gas tax that is levied uniformly across industries and activities is considered to be a particularly cost-effective way to reduce emissions.[19] This is because a uniform tax, in theory, ensures that emissions are reduced first where it is cheapest to do so. This minimizes the costs of the transition.[20]

Inclusion can also be ensured via technical standards for greenhouse gas emissions. This may be particularly relevant if greenhouse gas taxes cannot be levied in a simple way, but a technical rule can easily be defined. For example, more stringent insulation requirements or requirements to cool and acidify slurry can reduce emissions.[21] Technical standards implicitly increase the cost of greenhouse gas emissions, thus imposing a "shadow price" on the emissions.

The transition to a green economy requires large investments

Inclusion gives private companies an incentive to make green investments. It is primarily up to the financial sector to provide financing for the new investments, subject to sound risk management.[22]

In some cases, it may be necessary for the public sector to catalyse private know-how and financing.

18 IPCC (2018).

19 Energy taxes are not cost-effective. The reason is that they do not consider differences in greenhouse gas emissions across energy sources. Renewable energy thus becomes too expensive in comparison with fossil energy. Furthermore, an energy tax does not consider emissions from other sources than energy production, e.g. land use in agriculture.

20 The IMF (2019) proposes a globally uniform carbon tax of 75 dollars, as it is immaterial from what activities or where in the world reductions in emissions occur.

21 Danish Council on Climate Change (2020).

22 The role of the financial sector in relation to climate change and the transition to a green economy is elaborated on in Danmarks Nationalbank (2019) and Krogstrup (2021).

This could be in the form of public-private partnerships in large-scale infrastructure projects, e.g. the development of sustainable electricity grids. There may be a need for involvement, because the projects concern areas with intense public regulation. It may also be due to high start-up costs, which hamper private willingness to undertake projects despite a sufficient demand for the projects to generate a social return.[23]

Public co-funding of green basic research may be needed. Basic research is often a *public good*, i.e. a good that benefits all of society, but without being patentable. The private incentive for basic research is thereby too small relative to the return for society.

Public involvement may also be necessary for small and medium-sized enterprises to alleviate credit restrictions. Guarantee and surety schemes and lending programmes are particularly relevant here.[24]

Public subsidies for investment have been highlighted as a potential compensation for incomplete inclusion of the social costs of greenhouse gases in the price of emission.[25] However, this solution makes the transition more expensive than a uniform greenhouse gas tax, which, as previously mentioned, is cost-effective.

Information on companies' reliance on emissions corrects market failures

In principle, inclusion and investments bring about the right conditions for a transition, since the requisite incentives and subsidy schemes are in place. In practice, however, further market failures may prevent the transition from happening.

Another market failure is *information frictions*. They obscure the consequences of climate change and the transition for companies' business models. The transition has no historical precedent. Therefore, there are no historical data for how it will proceed. In addition, many companies lack knowledge about their value chains' reliance on greenhouse gas emissions. This is partly due to common reporting requirements and a systematic collection of data on companies' emissions not yet being in place.[26]

The information frictions make it difficult for companies to assess and communicate the profitability of green investment plans. It may also be difficult for banks and investors to assess any negative consequences for corporate profitability of non-transition. The market price of emissions-intensive companies thus does not reflect the non-transition to the same extent as with full information.[27]

Another market failure is *short-termism*. The failure refers to the fact that the assessment of some managements is based too much on the short-term results of their companies. This can create a situation in which companies do not transition even if it makes sense in terms of long-term profitability.[28]

Guidelines for climate-related reporting can ensure information about companies' reliance on greenhouse gas emissions and contribution to the transition. In this context, EU's *green taxonomy* is an important initiative. The taxonomy sets common standards for whether a given economic activity can be regarded as contributing to the transition.

23 Public projects are typically not subject to as stringent requirements for how quickly they are to be repaid as private projects. This reflects that social discount rates are typically lower than private discount rates. Future returns are so discounted more heavily in private projects than in public projects. Certain green projects are therefore regarded as unprofitable from a private financial perspective and profitable from a societal perspective.

24 Examples of publicly owned investment funds with green objectives in Denmark are *EKF Denmark's Export Credit Agency*, *the Investment Fund for Developing Countries*, *the Danish Green Investment Fund* and *Vaekstfonden*.

25 Public subsidies for green investments are highlighted as the main driver in achieving the Paris goals in the proposal for a *Green New Deal* in the US, see Ocasio-Cortez (2019).

26 OECD (2020a) probes into sustainability ratings across companies and rating agencies. The study finds large differences and inconsistencies across the agencies. The study also finds that, in some cases, "better" ratings are associated with higher (not lower) CO_2 emissions. Similar conclusions are reached in Berg et al. (2020) and Elmalt et al. (2021).

27 Information frictions are more specifically referred to as *asymmetric information* if company managements are themselves aware of the importance of non-transition to profitability, but conceal this information from external parties.

28 Admati (2017).

Measures are most efficient if they are announced in advance for a time horizon that is relevant to investment decisions

The economic literature points out that measures aimed at inclusion, investments and information have a greater effect if they are communicated in a tangible and credible form in advance. This creates clarity about which measures will apply when. Companies and households are so better able to assess what they can save on lower greenhouse gas taxes in the future by reducing their emissions today. This increases the private investment incentives at the announcement date of the measures. Conversely, if there is uncertainty about future measures, companies and households may decide to postpone investments until there is clarity about the future costs of emissions. It postpones the transition, and makes it more expensive.

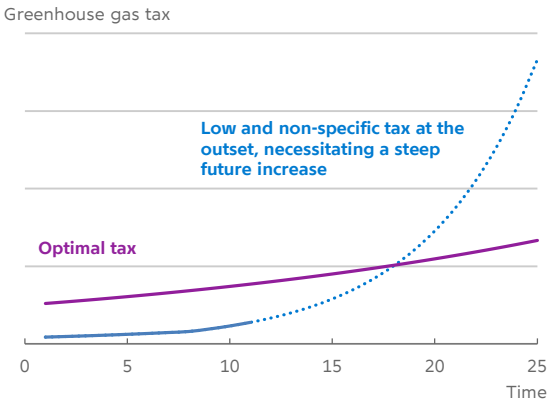
An alternative to greenhouse gas taxes is emission trading systems.[29] Some economists prefer taxes over trading systems, because taxes provide greater certainty about the current and future prices of emissions.[30] Taxes are easy to administrate and communicate, since they build on the existing taxation infrastructure.[31] In addition, taxes mobilise revenue, which can be spent on redistribution between households or as compensation to businesses.[32]

Models for greenhouse gas taxes recommend that taxes be increased at a modest pace until the climate goals are met.[33] The purple line in chart 2 illustrates such a development. In turn, the blue line in chart 2 shows a development with delayed action. Here, the tax is low at the outset, and it has not been specified in advance. The tax will therefore have to rise much more drastically later on to achieve the same reduction in emissions that could have been achieved with an initially slightly higher and pre-announced tax.[34]

An unexpected, steep increase in greenhouse gas taxes leads to an economic loss in many cases. This happens if taxes imply that the capital stock cannot be used profitably or resold for other purposes. Conversely, a pre-announcement of taxes reduces the

Greenhouse gas taxes should be announced in advance and increase at a modest pace

Chart 2



Source: Own illustration.

29 An emission trading system requires companies to be in possession of an allowance for emitting greenhouse gases. Allowances are traded in the system. This gives companies an incentive to reduce their emissions, so they can sell allowances and avoid buying buy new allowances.

30 The price of greenhouse gas emissions fluctuates in emission trading systems depending on the supply of and demand for allowances. Fluctuating prices may lead to large fluctuations in producer prices, especially at the outset of the transition period, when the emission intensity is high. This compounds the costs of the transition. See also Stavins (2019), who compares different schemes for taxation of greenhouse gas emission.

31 Stavins (2019), Batini et al. (2020).

32 Redistribution to households that lose purchasing power as a result of inclusion measures (e.g. higher energy prices) has historically been decisive for the ability of policymakers to implement the measures, see Shang (2021).

33 Models for greenhouse gas taxes recommend a rate of increase for the tax between the risk-free interest rate and the growth rate of the economy, see Van der Ploeg (2020).

34 A delayed greenhouse gas tax increases current emissions, as it encourages a fire sale of fossil fuels before taxes rise. This is the *green paradox*, see Sinn (2012).

risk of investments becoming unprofitable over their life. This ensures a beneficial use of resources.

A pre-announcement of greenhouse gas taxes also supports financial stability. This is again due to knowledge of future tax levels diminishing the risk that investments become unprofitable to use. In addition, increased knowledge of the transition supports a more accurate risk management in the financial system. This point is elaborated on later in the analysis.

Economic consequences of climate change and the transition

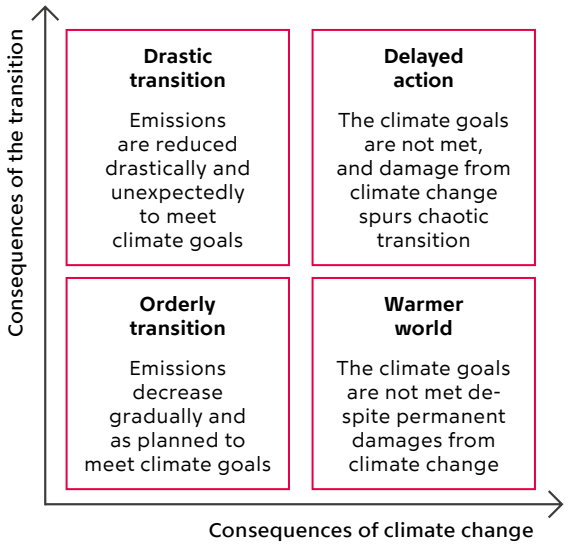
Climate change is already affecting the global economy today. Its impact is likely to grow in the future. A successful transition to a green economy requires historically unprecedented rapid changes in energy production and agriculture. Both climate change and the transition will therefore impact the economy and the financial system to some extent. Due to the scale of the changes, this may challenge the objectives of price and financial stability, which central banks typically have a co-responsibility for ensuring. It is against this background that central banks now focus on the climate.[35]

The consequences of climate change and the transition are frequently divided into *physical risks* and *transition risks*. However, the designation of these consequences as risks is often misleading, being that the consequences are expected to occur and are often already occurring. Conversely, the term "risk" is generally used to describe future *downside* outcomes, i.e. outcomes that are less favourable than the expected future outcome.[36]

The scope of the consequences varies

The economic and financial consequences of climate change and the transition depend on whether, and how quickly, the transition is implemented. This is illustrated on a global scale in chart 3.

Economic consequences of climate change and the transition to a green economy Chart 3



Source: Inspired by NGFS (2019).

The best-case scenario (bottom-left corner) is an orderly transition. However, this scenario seems increasingly less likely, in that sufficient measures have yet to be adopted in the individual countries for the world to reach the Paris goals through a gradual transition.[37] In the worst-case scenario (top-right corner), a rapid transition does not occur until the damages from climate change become sufficiently severe. Outside these two extreme scenarios, policymakers are, in theory, faced with a trade-off between consequences of climate change and the transition.[38]

It is difficult to make accurate projections of climate change and the transition. One reason for this

35 See European Investment Bank (2021a), IMF (2020, Chapter 3) and NGFS (2020) for a review of the literature.

36 A third consequence is *liability risks*. They may arise as a result of legal actions from claimants who have incurred a loss due to climate change and who seek damages from the parties that they regard as liable, see Financial Stability Board (2020). Liability risks may also affect insurance companies through their general liability insurance.

37 If the current national commitments to reduce emissions of greenhouse gases are implemented fully, global reductions by 2030 will be approx. 1/5 and 1/3 of those necessary to reach the 1.5°C and 2.0°C goals, respectively, see UNEP (2020).

38 There is probably no trade-off for small countries, since they cannot unilaterally influence climate change.

is great uncertainty about future climate action. However, for climate change, another reason is *tipping points* that abruptly and irrevocably aggravate the impact of greenhouse gas emissions and global warming on the climate. Examples of possible tipping points are deforestation of the Amazon rainforest or melting of the Greenland ice sheet. As a result, there is a significant risk that the consequences of climate change will be worse than expected. A scenario with a warmer world may so end up being costlier in the long run than a scenario with delayed action.

Economic consequences of climate change

The literature describes two principal impacts of climate change on the real economy: changed productivity and destruction of assets. In addition, a need for climate adaptation (e.g. installation of air-conditioning and establishment of dikes) entails costs for households, companies and governments.

Global warming can, on average, lead to increased productivity in cold climate zones and lower productivity in hot climate zones. The impacts propagate through different channels.[39] Heat stress already today lowers labour productivity in industries with much outdoor activity. This impact is likely to increase in the future, especially in hot climate zones.[40] In addition, yields from agriculture, horticulture and forestry are likely to fall in warm climate zones and increase in cold climate zones. This is due to changes in the types of crops that can be grown, conditions for pollinators and irrigation costs.

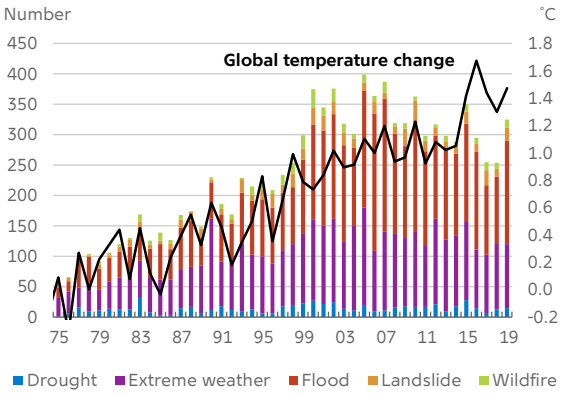
Finally, fish farming yields may fall, as greenhouse gases acidify the seas, thus slowing down the reproduction of marine fish.[41] Returns from hotels and restaurants may also increase or decrease, depending on the specialisation of individual countries in tourism.

Climate change will also increase the frequency and severity of natural disasters. This development has already begun, see chart 4. Natural disasters disrupt production processes, which, on average, lowers productivity. Natural disasters also mean that productivity levels may vary more over time. For instance, this is the case in agriculture and forestry, where yields may become more uncertain due to periods of drought, flooding or wildfires.[42]

The productivity effects described may lead to higher production costs and lower economic activity in hot climate zones. Conversely, costs may decrease and activity increase in cold climate zones if the favourable effects of a warmer climate dominate the adverse effects of natural disasters. Concurrently, the fluctuations in costs and activity unequivocally increase as a result of natural disasters. The effects may propagate to consumer prices and competitiveness, thus impacting households' purchasing power. The effects may also make themselves felt abroad via foreign trade.

Natural disasters also destroy tangible assets (e.g. roads, buildings and computer servers) and intellec-

The global number of natural disasters has increased considerably Chart 4



Note: The chart shows the global number of natural disasters (left axis) and the global temperature increase relative to the average temperature in 1951-1980 (right axis).
Source: Macrobond.

39 Burke, Hsiang and Miguel (2015), Deryugina and Hsiang (2014), European Investment Bank (2021b).

40 Global labour productivity loss due to heat stress is expected to increase from 1.4 per cent in 1995 to 2.2 per cent by 2030, subject to the achievement of the 1.5°C goal, see ILO (2019).

41 Baumann et al. (2012), Frommel et al. (2012).

42 Noy (2009), Fomby et al. (2013), Felbermayr et al. (2014), Parker (2016).

tual capital (e.g. documents) stored in tangible assets. This causes a loss for the owners of the assets. In some cases, the loss in value will occur already before the disaster, based on an anticipation of increased frequency and severity of natural disasters. For instance, this may be the case in the event of an elevated risk of flooding of coastal homes.

Natural disasters have negative financial consequences

Credit institutions will incur losses if owners who have lost assets during a natural disaster default on their loans. This is especially the case if the assets (e.g. homes) that have depreciated are pledged as collateral for the debt. The risk of natural disasters varies geographically. To the extent that there are local differences in the lending of individual credit institutions, there may be large differences in how hard the individual credit institutions will be hit.[43]

Another type of consequences concerns insurance companies. Here, natural disasters will result in claims for compensation that are larger and more difficult to foresee than what has historically been the case. That development has already begun. Insurance companies can react by refraining from writing insurance policies or by raising premiums to a prohibitively high level. If so, households and companies will be left without cover for natural disasters. This increases the economic losses following disasters, due to greater fluctuations in private consumption. At the same time, inability to service debts may have a negative impact on credit institutions.[44]

Finally, there is a risk that climate change could challenge the sustainability of sovereign debt. It is again most topical in the countries that will be hardest hit by the changes. Costs for climate adaptation and assistance to households and companies following natural disasters may cause large budget deficits. At the same time, declining productivity due to warming and natural disasters may gradually erode the tax base.[45]

Economic consequences of the transition

The transition to a green economy differs fundamentally from past socio-economic transformations, such as industrialisation and globalisation. The past transformations had a longer time horizon than that assumed for the transition to achieve the Paris goals. In addition, the past transformations were market-driven and mainly supported by technological progress, which made existing business models unprofitable. Conversely, the transition to a green economy must to a large extent be driven by policy measures and changes in consumer preferences. Some existing technologies will thus become obsolete – not because they are not competitive in the absence of inclusion measures – but because they pollute. Together with differences in speed, this may make the transition to a green economy more challenging than the past transformations.

Inclusion measures, such as greenhouse gas taxes, increase the cost level in companies with large emissions, unless the companies can reduce their emissions through cost-effective technical solutions. If cost levels rise, this may be passed on to producer prices in the same way as a shock to commodity prices propagates. This will – also via value chains – reduce the demand for goods and services that rely on the possibility of emitting greenhouse gases.

A decline in the demand for emission-intensive products and services can lead to a decline in employment. But other jobs are also created, and the overall employment impact is therefore unclear.[46] For instance, more skilled labour may be needed for energy renovation projects and installation of new technology. This may give rise to a temporary shortage of labour in certain industries and push up wages.[47]

Assets could become "stranded" on account of the transition

A stranded asset is an asset that has suddenly lost its value. Commodities may become stranded because they are not profitable to extract or because extraction is prohibited by regulation. A large part of all coal, oil

43 Danmarks Nationalbank (2019), Mirone and Jygert (2021).

44 Financial Stability Board (2020), Swiss Re Institute (2020).

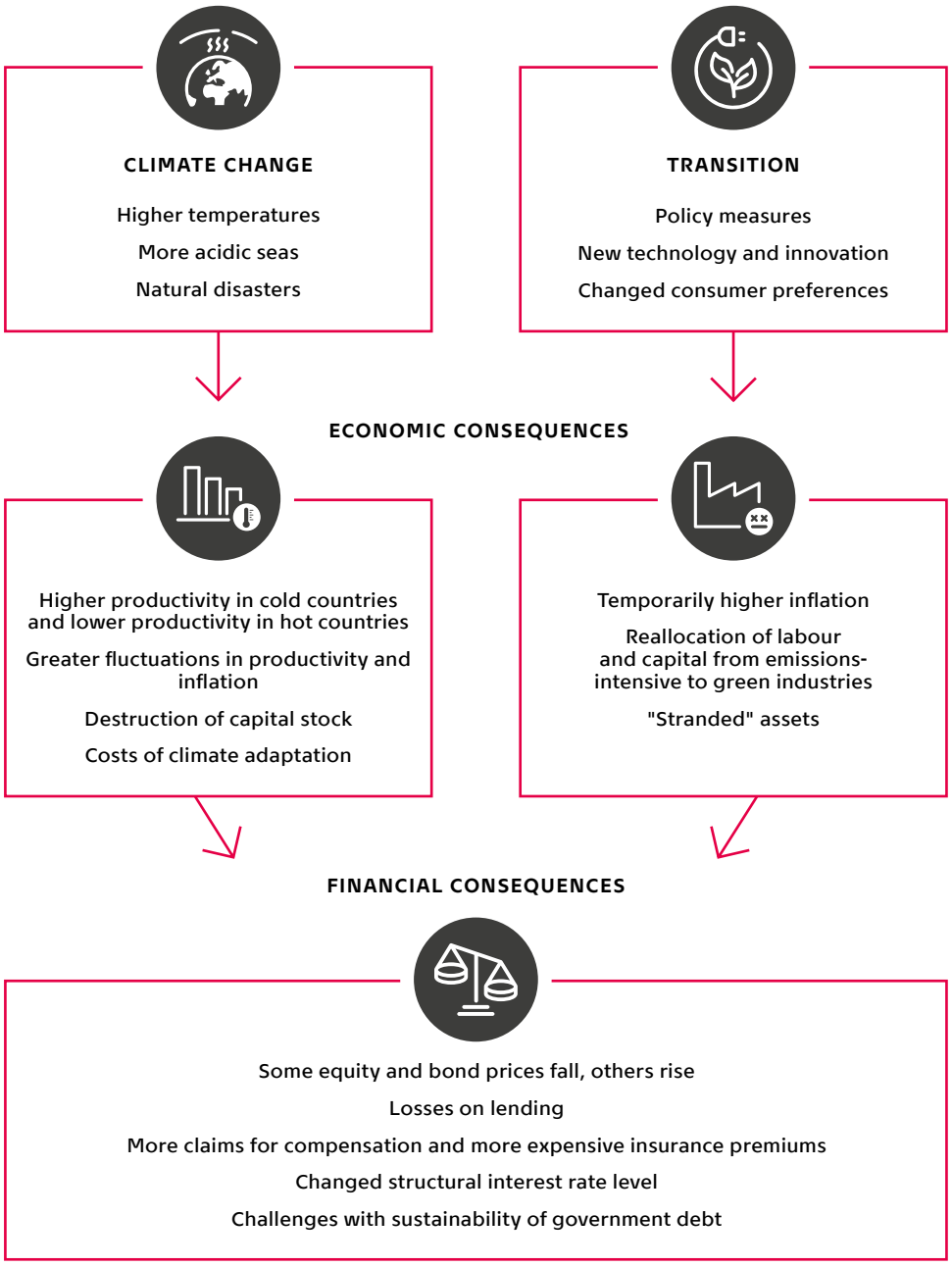
45 Volz et al. (2020), Klusak et al. (2021), OECD (2021b).

46 The number of jobs created in the manufacturing and private service industries, among other industries, is about equal to the number of jobs lost in agriculture and the food industry if a uniform greenhouse gas tax is introduced in Denmark to achieve the 70 per cent target by 2030, see Danish Economic Councils (2021).

47 Batini et al. (2021), Mohommad (2021), OECD (2021a).

Transmission of climate change and the transition to a green economy

Chart 5



and natural gas reserves in the world must become stranded if the 2°C goal is to be met globally.[48]

Capital stock in emissions-intensive production may also become stranded. This will be the case if the transition implies that the capital stock cannot be used profitably or resold for other purposes. This may be the case with coal, oil or natural gas-fired power plants.

Stranded assets result in an immediate loss for the owners. However, the losses may spread to credit institutions if the affected owners default on their loans or if the stranded assets have been posted as collateral.

Incorrect pricing of the transition is a threat to financial stability

An important question is whether banks and investors predict that equities, loans and bonds related to emissions-intensive production are likely to depreciate during the transition. If this is the case, the expectation should be reflected in the interest rate on the loans and bonds and in the prices of the equities. The reason is that risky assets are usually traded at higher interest rates and lower prices to compensate banks and investors for the extra risk. If, conversely, the financial system does not expect losses on emissions-intensive assets, the assets may end up with banks and investors who do not have the capacity to absorb any losses that may arise anyway. This could pose a challenge to financial stability.[49]

Economists are continuously examining how banks and investors price the transition. Some studies find that prices are *slightly* lower on emissions-intensive equities than on comparable non-intensive equities.[50] The negative price premium is mainly due to the equity markets reacting to uncertainty about future climate regulation.[51] There are also studies finding that emissions-intensive companies pay higher interest on loans, as compared with non-intensive companies.[52] At the same time, however, there are studies that do not detect any pricing of the transition.[53]

One possibility is that the limited – or completely absent – pricing is due to the financial markets assessing that companies will not be forced to transition within a relevant time horizon. Another possibility is that the markets do not have the necessary data to assess the impact of the transition on corporate profitability. This possibility is supported by the lack of systematic collection of emissions data, as well as large differences in sustainability ratings across rating agencies. This underlines the need for better reporting and further analysis.[54]

Climate change could limit central banks' ability to support economic activity

Climate change and the transition may affect the global structural interest rate level, i.e. the interest rate level around which actual interest rates move. The structural interest rate level has been declining over several decades.[55] If the level falls further, this could lead to a need for lower monetary policy rates across central banks to avoid an economic slowdown. The reason for this is that policy rates are set in relation to the structural level. Some central banks can therefore be more liable to hit the effective lower bound on their policy rates. This hampers their ability to support economic activity.

The impact of climate change and the transition on the structural interest rate level is theoretically ambiguous. Increased uncertainty and expectations of economic losses lead to increased precautionary saving by households and companies. In addition, slow productivity growth lowers the demand for financing of investments. These effects point towards lower structural rates. Conversely, more investments in connection with the transition and climate adaptation increase the demand for financing, which pulls towards higher structural rates.[56]

48 McGlade and Ekins (2015) find that a third of all oil reserves, half of all natural gas reserves and 80 per cent of all coal reserves must remain underground if the 2°C goal is to be met globally.

49 Incorrect pricing has historically played a significant role in financial crises. As an example, this was the case when the risk on US mortgage loans was underestimated before the 2007-2009 financial crisis.

50 Bolton and Kacperczyk (2021a,b).

51 Faccini et al. (2021), Hsu et al. (2020).

52 Delis et al. (2021), Ehlers et al. (2021).

53 Görgen et al. (2020).

54 OECD (2020a), Berg et al. (2020), Elmalt et al. (2021).

55 Pedersen (2015).

56 Bylund and Jonsson (2020), Dietrich et al. (2021).

Central banks and climate change

Many central banks are currently exploring how climate change and the transition will impact the economy. The content of the work varies from central bank to central bank, depending on mandates and other country-specific conditions. This section introduces some of the topics that are being examined.

Central banks work with climate issues

Central banks' analytical efforts focus, in particular, on understanding the transmission channels from climate change and the transition to the economy and the financial system. In this context, *Network for Greening the Financial System* (NGFS), which is a network of currently 92 central banks and supervisory authorities, plays a key role in the exchange of knowledge and best practices.[57]

Central banks and the NGFS develop climate scenarios with varying intensities of climate change and transition. The scenarios describe the development in, e.g., greenhouse gas taxes, prices, investment, food production and financial variables over time. Work is currently being done to make the scenarios more accurate and to include more economic variables in the descriptions.[58] The scenarios may be of importance in an assessment of whether there will be a periodical need to adjust monetary policy if, say, taxes or the demand for skilled labour in green industries push up inflation.

A growing number of central banks use stress tests to examine whether some credit institutions and insurers are particularly vulnerable to climate change and the transition.[59] Stress tests typically simulate write downs of loans to emissions-intensive companies, including companies that rely on emissions through value chains. The market value of the companies may also fall. Stress tests can also simulate write downs of mortgage loans due to falling prices on homes that are expensive to heat or located in areas at risk of flooding. The write downs are meant to reflect that borrowers default on their loans and that any collateral on the loans decreases in value. The speed and extent of the write downs may vary, which reflects differences in the intensity of climate change and transition.[60]

Central banks are also exploring whether climate-related risks are being priced in financial markets. The work is of importance in context of identifying risks to financial stability.[61] A result of the work may be recommendations for political systems and financial institutions to ensure better management of climate-related risks. Some central banks are also responsible for supervising the financial sector. Here, an adjustment of financial regulation may become relevant if climate change and the transition make certain types of lending or investment riskier, without this being sufficiently reflected in the exposure of the sector and asset prices.

Climate change and the transition are also of importance to central banks' portfolios

Central banks handle different sources of risk when managing portfolios and performing monetary policy operations. In the light of new climate-related risks, some central banks may decide to adjust their investment strategy to ensure expe-

57 Website: *(link)*.

58 Bank of England (2019), European Systemic Risk Board (2020), Mirone and Jygert (2021), NGFS (2021).

59 Climate stress tests can be performed in different ways. In a fully developed stress test, the climate-related macroeconomic effects are modelled in the stress test model. This ensures consistency between climate and macro effects and financial effects. However, one challenge with fully developed models is that they are resource-intensive to develop and maintain, and there is no consensus on what they should look like. An alternative to fully developed models is sensitivity analyses in ordinary stress test models. Here, write downs and slumps in asset prices are assumed – based on data outside the model – to be more prominent in climate-exposed financial institutions than in other institutions.

60 Allen et al. (2020), De Guindos (2021), European Systemic Risk Board (2020), Helmersen et al. (2020), Vermeulen et al. (2018).

61 Faccini et al. (2021).

Work with climate and sustainability in Danmarks Nationalbank Box 1

Danmarks Nationalbank's climate and sustainability work is anchored in a bank-wide analytical agenda. The following areas are part of the agenda:

- **External cooperation:** Danmarks Nationalbank is a member of the NGFS. Danmarks Nationalbank also follows the development of *GreenREFORM*, which is a climate-economic model of the Danish economy.
- **Macroeconomic analysis:** Danmarks Nationalbank examines the consequences of climate change and the transition on economic variables, such as prices, employment and competitiveness. Micro- and macroeconometric methods are used.
- **Financial analysis:** Danmarks Nationalbank examines the financial consequences of climate change and the transition. The work includes stress tests, as well as identification of flooding risk and of pricing of climate-related risks in the housing market and financial markets.
- **Issuance of green government debt:** Danmarks Nationalbank explores the possibility of issuing green government bonds on behalf of the Ministry of Finance. This could lower the price of green public investment and contribute to the establishment of green financial markets.
- **Responsible investment:** Danmarks Nationalbank adheres to the *UN Global Compact* principles for responsible investment. Danmarks Nationalbank thus excludes companies that violate certain sustainability goals from its foreign exchange reserve. Danmarks Nationalbank is also examining how it can measure whether the companies in which the foreign exchange reserve is invested are transitioning in alignment with the Paris goals.
- **Physical operations:** Danmarks Nationalbank is continuously working to reduce greenhouse gas emissions. This is done through a number of initiatives, including solar cells, which contribute with approx. 100,000 KWh per year, the use of harbour water for cooling of premises and a fixed annual energy pool, which is used for new energy-saving measures.

The work is also described in Governor Signe Krogstrup's speech at the annual meeting of the *Association of Local Banks, Savings Banks and Cooperative Banks in Denmark* in 2021, see Krogstrup (2021) or (*link*).

dient risk management.[62] Central banks may also consider whether it is necessary to adjust their collateral requirements on lending facilities to commercial banks to adapt the basis to climate-related risks.[63]

Many central banks adhere to guidelines for responsible investment. The guidelines vary from central bank to central bank. In some cases, the guidelines are designed to prevent central banks from investing in assets that are systematically and significantly involved in activities which the central banks' governments oppose. A growing number of central banks are examining whether they can ensure that the companies in which portfolios are invested transition in alignment with the Paris Agreement. The work is again complicated by a systematic collection of data on companies' emissions not yet being in place.

Some central banks disclose their climate-related financial exposures.[64] The reports typically contain information on governance, strategy and risk management internally in the central bank. In some cases, the reports contain explicit indicators and targets for climate-related risks. For example, central banks' carbon footprints are often used as an indicator of risks connected with the transition.[65]

62 Sveriges Riksbank excludes certain greenhouse gas-intensive assets from its foreign exchange reserve and asset purchase programme to shield itself from climate-related risks, see Sveriges Riksbank (2020).

63 A method for evaluating the vulnerability of a portfolio to the transition is temperature scenarios. Temperature scenarios do not value risk in terms of money. Instead, the method measures the gap between a given climate goal and emissions from the companies in a given portfolio. Temperature scenarios are proposed as a measure of financial risks associated with the transition in TCFD (2017, 2020). See Oustry et al. (2020) for an application to collateral pledged in the Euro system.

64 Bank of England (2020), Banque de France (2021), Hyrske (2021), De Nederlandsche Bank (2021).

65 The carbon footprint can be interpreted as the gap between a central bank's current climate impact and a goal of climate neutrality.

Adaptation to climate-related risks may mitigate climate change

Central banks contribute to the transition by meeting their objectives to ensure price and financial stability. A stable economy creates good conditions for a transition to take place. Stable planning horizons for households and companies bring about a solid basis for long-term green investments. Stability also adds to fiscal space and ensures low financing costs. This makes green investments more affordable.

Central banks' contribution to an increased knowledge on the financial consequences of the transition can in itself lead to transition. The same applies to disclosure requirements for companies and financial institutions. Increased awareness of the risks associated with emissions-intensive companies may mean that investors rate these companies as riskier. Thus, financing is diverted away from this market segment, and the risks connected with the transition will be priced. Companies that oppositely are able to substantiate that they are transitioning will be able to obtain cheaper financing conditions. Overall, the incentive to transition is thus strengthened.[66]

Central banks will also tackle climate issues differently in the future

Central banks are continuously reviewing their role in relation to climate change and the transition to a green economy. This is reflected in the strategy review of the ECB's monetary policy, which is expected to be published this year. Here, climate change is a key topic.[67]

There is growing consensus on the importance of central banks taking the consequences of climate change and the transition into account when attending to their core purposes of ensuring price and financial stability. However, the development of the most expedient approaches and tools is still ongoing.

In turn, there is no consensus as to whether central banks also have a role in explicitly contributing to the transition. A proposal that is sometimes discussed is whether central banks should use monetary policy or financial regulation actively to support the transition. This could, for example, be through green asset purchase programmes or green lending to non-financial companies.[68] Monetary policy instruments can partly emulate the effects of tax incentives and of public investment funds. The similarity is that the measures make certain types of investments more expensive to make, while others become cheaper.

However, there is no advantage of using monetary policy instruments to support a transition, as compared with tax incentives and publicly owned investment funds. There may instead be significant disadvantages. Firstly, central banks hardly have the necessary expertise that banks and investment funds have for risk management of guarantees, sureties and loans to private companies. Secondly, the use of monetary policy tools for meeting climate goals could clash with other monetary policy goals, such as the Danish fixed exchange rate policy. This makes the transition more expensive for society than necessary. Thirdly, central banks do not have the democratic legitimacy required to make the choices and trade-offs involved in executing a climate policy.[69]

It is to be expected that central banks will continue to tackle climate issues in different ways. Climate change and the transition will affect countries differently. This naturally creates a need for different approaches. Differences in mandates furthermore mean that central banks do not react in the same manner.

66 The effects presuppose that assets with different climate characteristics are incomplete substitutes in financial markets.

67 Lagarde (2021).

68 Central banks use asset purchase programmes to support economic activity by buying, e.g., bonds in financial markets. This lowers the level of interest rates. Under a green asset purchase programme, a central bank adjusts its purchases, so that it either buys more bonds from green companies or fewer bonds from emissions-intensive companies.

69 The tools used by central banks should be as distributionally neutral as possible, as their managements are typically not appointed through direct democratic processes.

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PUBLICATIONS

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News offers quick and accessible insight into an Analysis, an Economic Memo, a Working Paper or a Report from Danmarks Nationalbank. News is published continuously.

ANALYSIS

Analyses from Danmarks Nationalbank focus on economic and financial matters. Some Analyses are published at regular intervals, e.g. *Outlook for the Danish economy* and *Financial stability*. Other Analyses are published continuously.

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Reports comprise recurring reports and reviews of the functioning of Danmarks Nationalbank and include, for instance, the *Annual report* and the annual publication *Danish government borrowing and debt.*

ECONOMIC MEMO

An Economic Memo is a cross between an Analysis and a Working Paper and often shows the ongoing study of the authors. The publication series is primarily aimed at professionals. Economic Memos are published continuously.

WORKING PAPER

Working Papers present research projects by economists in Danmarks Nationalbank and their associates. The series is primarily targeted at professionals and people with an interest in academia. Working Papers are published continuously.

The analysis consists of a Danish and an English version. In case of doubt regarding the correctness of the translation the Danish version is considered to be binding.

DANMARKS NATIONALBANK
LANGELINIE ALLÉ 47
DK-2100 COPENHAGEN Ø
WWW.NATIONALBANKEN.DK

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Lasse Jygert
Principal Expert
ljy@nationalbanken.dk
FINANCIAL STABILITY

Marcus Mølbak Ingholt
Senior Climate Economist
mmi@nationalbanken.dk

Anne Brolev Marcussen
Principal Economist
ECONOMICS
AND MONETARY POLICY

CONTACT

Ole Mikkelsen
Communications
and Press Officer
omi@nationalbanken.dk
+45 3363 6027
SECRETARIAT
AND COMMUNICATIONS

DANMARKS NATIONALBANK