Economic Commentary

An overview of the economic consequences of the NGFS climate scenarios

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Economic Commentaries

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An overview of the economic consequences of the NGFS climate scenarios[1]

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In 2021, the global sustainability network known as *the Network for Greening the Financial System* published a number of scenarios on climate change and economic developments. In this Economic Commentary, we present an overview of these scenarios. Among other things, the scenarios show that the economic cost in terms of GDP is relatively small at a global level. This is also the case for Sweden, where the cost is even smaller. From a monetary policy perspective, the scenarios show that under certain conditions Swedish inflation may be higher. In calculating the scenarios, physical and transition risks are taken into account. However, the risk of tipping points is not accounted for. Tipping points may have significant environmental and economic consequences if they occur.

1 The economic consequences of climate change need to be quantified

Limiting climate change and global warming in line with the Paris Agreement to 1.5–2°C above pre-industrial levels (1850–1900) will be one of the most important tasks for society in the coming decades.[2] If society fails in this, there will be serious consequences for biodiversity and the nature's ecosystems, as well as for economic developments and welfare.

First and foremost, to limit global warming measures are needed to make carbon dioxide (CO_2) emissions more expensive globally.[3] Moreover, new research and development is needed to provide better technology to limit emissions from the steel industry, cement production and heavy transport, for example. Households and firms need to start planning for the risks and vulnerabilities that climate change entails. To the extent that risks arise in the financial system they need to be made visible, since central banks and supervisory authorities must consider them to safeguard financial stability. From a

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[2] The Paris Agreement is an international climate treaty drawn up at the 2015 United Nations Climate Change Conference in Paris.

[3] For global warming, the total amount of greenhouse gas emissions – CO_2, methane and nitrous oxide – is what matters. However, CO_2 accounts for the largest part of warming by far.

monetary policy perspective, central banks need to understand the economic consequences of climate change to fulfil price stability.[4]

The risks posed by climate change are typically divided into two categories:

- **Physical risks**, i.e., risks arising from extreme weather conditions such as floods, storms, heatwaves and droughts.
- **Transition risks**, i.e., risks that affect the transition to a less fossil-based economy. This could include political decisions to raise taxes on CO_2 emissions, higher prices for emission rights or changed patterns of consumption.

It is difficult to predict the full consequences of climate change, even if our knowledge is constantly improving. Greenhouse gases remain in the atmosphere for a long time and it takes time for the climate to react to increased emissions. This built-in inertia in the climate system can have unpredictable effects. Climate change is also multifaceted and it is difficult to predict how changes in different parts of the ecosystem may interact with each other. There is also the risk of tipping points. These are changes in the ecosystem that are hardly noticeable at the beginning of the process – but when a certain threshold value is exceeded – large and often irreversible changes occur. Tipping points can occur in different parts of the ecosystem, e.g., the Arctic polar ice, the Siberian permafrost or the Amazon rainforest. Our knowledge of tipping points is, however, limited, but they cannot be ruled out. Finally, we know that many countries are planning to limit emissions, but it is difficult to know if these plans are sufficient.

According to the latest IPCC report, global warming has been faster and more irreversible than previously thought.[5] Within the next 20 years, the Earth's average temperature will have risen by over 1.5°C since the pre-industrial period. If greenhouse gas emissions continue at the current rate, the temperature will exceed 2°C during the 22nd century. At present, the temperature has risen by around 1.1°C. Weather events such as floods, storms, heatwaves and droughts are therefore likely to become more common, more extreme and more prolonged in the future.

Scenarios: A way to quantify the economic consequences of climate change

As mentioned, the full consequences of climate change are difficult to predict, and this is also the case of the economic consequences. There are many reasons for this. The data available to make reliable empirical estimates of the economic consequences is limited. The global economy, like the climate, is a complex system, and it is difficult to include all relevant conditions and relationships in a simplified model. It is particularly difficult to model the risk of tipping points, due to large uncertainties in terms of their size, probability and interaction with each other. The economic consequences also vary

[4] See Breman (2020) for a discussion of how central banks work with sustainability and climate change, and Bylund and Jonsson (2020) for an analysis of how climate change may affect the long-term real interest rate, which is an important factor for monetary policy.

[5] See IPCC (2021). IPCC is an abbreviation of *Intergovernmental Panel on Climate Change* and is an intergovernmental climate panel within the UN, established in 1988 to compile research results on climate change.

greatly between individual countries and regions depending on, among other things, their adaptability. Moreover, there may appear new risks that were not considered in earlier calculations; an example of this is the risk that more people may become climate migrants. Finally, yet importantly, future technological developments are of great importance for the economic consequences of climate change; and this is something we know little about.

The uncertainty – surrounding climate change and the economic consequences – makes it difficult to construct accurate forecasts, i.e., to predict the most likely economic outcome. When uncertainty is large, *scenario analysis* is a viable alternative to standard forecasting. In a scenario, the calculations are conditional on a number of basic – but at the same time simplified – assumptions. These could be assumptions about political measures or temperature increases, for example. The outcome of a specific scenario is therefore not the most likely outcome. However, since the information from different scenarios illustrates how political decisions and human actions can affect the outcome, scenario analysis is an important tool in decision-making.[6] Hence, scenarios are both a way to highlight risks and to support planning.

NGFS climate scenarios

In 2021, the global sustainability network NGFS published a number of climate scenarios and the economic consequences for different parts of the world, including Sweden.[7] In addition, NGFS made the scenarios and related publications available on a new website.[8] This makes the scenarios readily available for financial firms when updating stress tests, for central banks and supervisory authorities in their work on climate-related risks and for academics in their research. If different climate-related analyses are based on a number of similar benchmark scenarios the results are more comparable, which should be an advantage.

The purpose of this Commentary is to present an overview of the NGFS climate scenarios and to show the economic consequences globally and for Sweden. The NGFS provides six main scenarios on their website, of which we have selected three:[9]

1. **Net Zero 2050.** Policy measures are implemented early to limit CO_2 emissions and these measures gradually become more stringent. The economy is expected to be carbon neutral around 2050 and warming is limited to 1.5°C. Both the physical risks and the transition risks are relatively small in this scenario.
2. **Delayed Transition.** CO_2 emissions are not expected to begin to decrease until 2030. This requires strong measures to limit warming to below 2°C and the rise in temperature becomes 1.8°C in the scenario. Transition risks are increased

[6] See Brainard (2021).

[7] See NGFS (2021b). NGFS is an abbreviation of *Network for Greening the Financial System*, a global network of central banks and financial supervisory authorities working to ensure that financial firms and authorities integrate climate and environmental risks into their work. The Riksbank and Finansinspektionen (Sweden's financial supervisory authority) participate on behalf of Sweden.

[8] See https://www.ngfs.net/ngfs-scenarios-portal/.

[9] The other three scenarios are "Below 2°C", which is similar to Net Zero 2050, "Divergent Net Zero", which is similar to Delayed Transition and "Nationally Determined Contributions" which is similar to Current Policies.

by the delayed implementation of measures, which means, among other things, that the price of CO_2 rises rapidly once the measures are implemented.

3. **Current Policies.** The current measures are maintained in this scenario, and there are no new measures to limit CO_2 emissions. This means that the global warming will be above 3°C by 2100 and that the physical risks will be more serious, for example from rising sea levels.

The economic cost in terms of global GDP is relatively small according to the scenarios. This is also the case for Sweden, where the cost is even smaller. From a monetary policy perspective, the scenarios show that Swedish inflation can be higher under certain conditions. Physical and transition risks are taken into account in these calculations. However, the risk of tipping points is not accounted for. Tipping points may entail significant economic consequences if they occur.[10]

2 What models have the NGFS used?

The NGFS has used a class of models known as *integrated assessment models* to calculate many of the scenarios.[11] These models were first developed in the 1970s, but have since been improved in different ways.[12] The basic principles of the early models, however, still apply, i.e., the models consist of three modules – one for the economic system, one for the carbon system and one for the climate system – that interact with each other.

The module of the **economic system** describes short and long-term economic relationships, including how economic activity creates CO_2 emissions and how political measures and technological developments may limit emissions. The modules for the **carbon system** and the **climate system** deal with the scientific basis of climate change. The module of the carbon system describes how the CO_2 generated by economic activity is distributed between the atmosphere, the sea and vegetation, while the module of the climate system describes how solar radiation is absorbed by the Earth and is then converted into heat radiation that disappears into space. In order for the climate to be stable, the solar radiation that heats the Earth must be in balance with the outgoing heat radiation that cools it. The CO_2 present in the atmosphere – which reduces the outgoing heat radiation – is part of this system.

Figure 1 illustrates how the three modules interact with each other. The module of the economic system first calculates a path for the CO_2 emissions. This path is used as input to the module of the carbon system, where a path for the CO_2 content in the atmosphere is calculated. This path is then used as input to the module of the climate system, which calculates the harmful effects caused by the CO_2 content in the atmosphere. The circle is closed by using these effects as input to the economic system. Output from the integrated assessment models includes paths for the CO_2 emissions and the average temperature. Among the economic variables, GDP is available on the NGFS website for

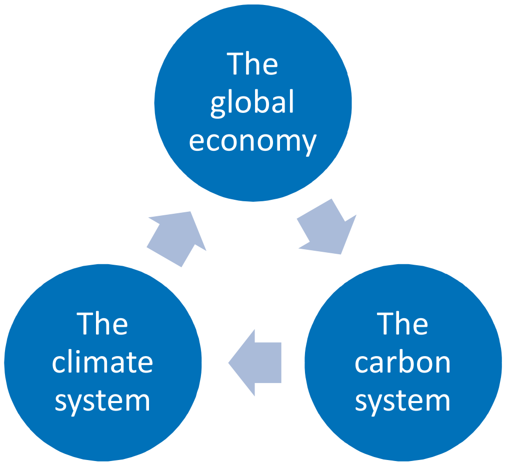
[10] See Dietz et al. (2021) for a summary of the impact of tipping points on the economy.

[11] These models have proved valuable in calculating the economic consequences of climate change, but they have also been criticised; see, for example, Stern and Stiglitz (2021).

[12] In 2018, William Nordhaus received the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel for his work in developing the first integrated assessment models.

several countries, including Sweden. The scenarios from the integrated assessment models cover time horizons up to 2100.

Figure 1. A schematic illustration of how the three modules in the integrated assessment models interact with each other



Source: Own illustration.

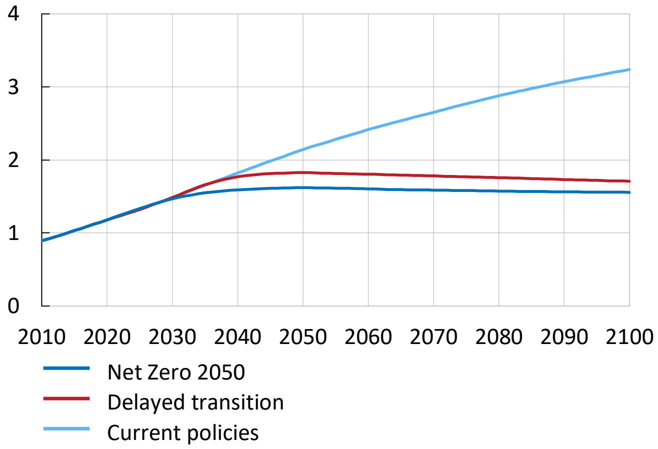
The NGFS has also used the macro model NiGEM – a model developed by *the National Institute for Economic and Social Research* – to calculate scenarios of the economic consequences. An advantage with NiGEM compared to the integrated assessment models is that it contains a more detailed economic modelling of many countries and regions. In addition, NiGEM contains a large number of economic variables such as GDP and its components, inflation, interest rates, exchange rates and house and equity prices. Input to NiGEM is the price of CO_2, a mix of primary energy sources, the use of energy services and the adverse effects of physical risks. Scenarios from this model extend to 2050.

3 Relatively small GDP effects at a global level

The goal of the Paris Agreement is to limit global warming to 1.5–2°C above pre-industrial levels. Figure 2 shows the paths of the temperature increase in the NGFS scenarios. In both the **Net Zero 2050** and **Delayed Transition** scenarios the Paris Agreement goal is achieved, even if the temperature increase becomes 0.3 degrees higher in the latter scenario. This somewhat higher temperature increase is in practice not insignificant, and may have negative consequences for the environment and the economy. In the **Current Policies** scenario, the temperature has risen by more than 3°C by 2100.

Figure 2. Global temperature increases in the scenarios

Degrees Celsius



Note. Temperature increases since pre-industrial period (1850–1900).

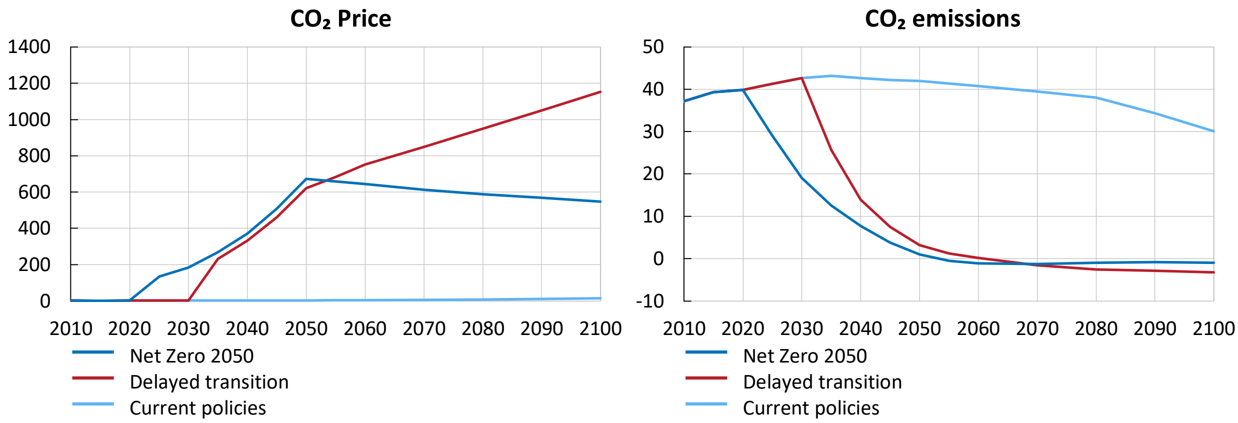
Source: IIASA NGFS climate scenarios.

The climate scenarios are based on different paths for the price of CO_2 and the amount of emissions, see Diagram 3. In the **Net zero 2050** scenario, the price increases up to 2050 when it levels out. In the **Delayed Transition** scenario, the price is unchanged from 2020 to 2030, when there is a rapid increase as strong measures are implemented to limit the emissions. The price continues to increase up to 2100. In the scenario **Current Policies**, the price remains unchanged throughout the course of the scenario.

The price of CO_2 affects the amount of emissions. In the scenario **Net zero 2050**, the CO_2 price rises today and the emissions start to decrease immediately. In the scenario **Delayed Transition**, emissions are constant up to 2030 when they start to decrease. There is slight increase of emissions until around 2035 in the scenario **Current Policies**, at this point the emissions start to decrease at a slow rate.

Figure 3. The price of CO_2 and CO_2 emissions in the scenarios

USD (2019) per tonne of CO_2 and gigatonnes of CO_2 per year



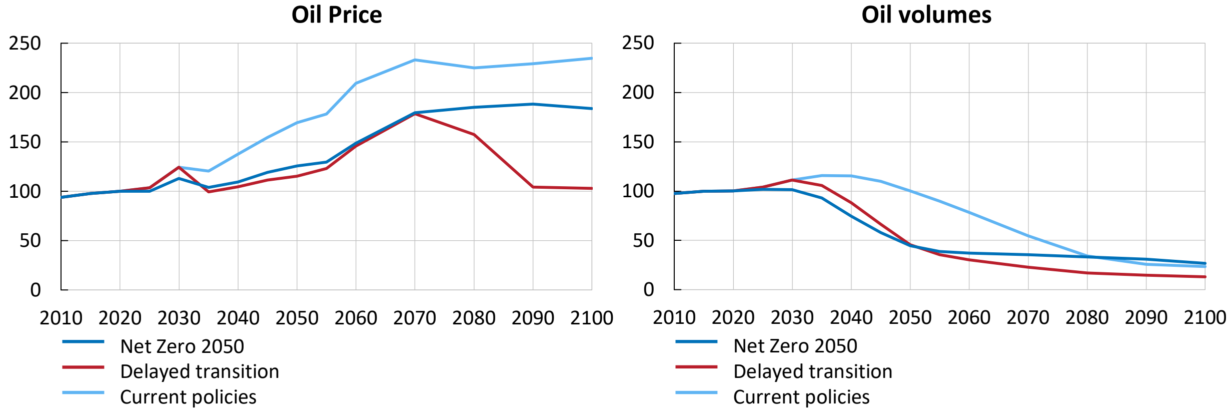
Note. CO_2 prices are weighted global averages.

Source: IIASA NGFS climate scenarios.

Diagram 4 shows the price and use of oil. In the **Net zero 2050** and **Current Policies** scenarios, the price is rising throughout the course of the scenarios. In the scenario **Delayed Transition**, the price increases until 2070 when it starts to fall and by 2090 the price is back at the 2020 level. The use of oil starts to decline around 2030–2040 in all three scenarios, and by 2100 the usage is at relatively low levels compared with today.

Figure 4. Oil price and oil volumes in the scenarios

Index: 2020 =100



Source: IIASA NGFS climate scenarios.

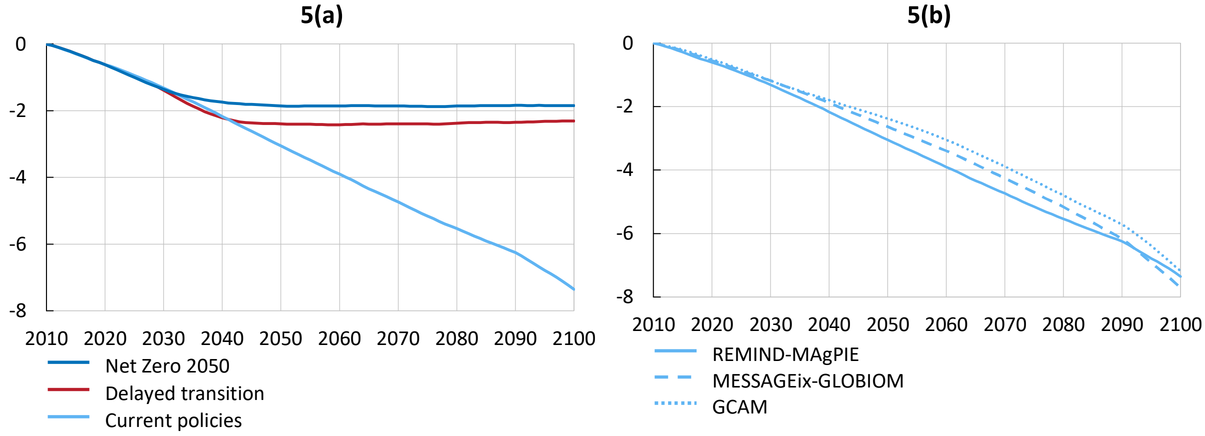
The NGFS provides scenarios for global GDP from three integrated assessment models.[13] Figure 5(a) shows global GDP from one of these, namely the REMIND-MAgPIE model. The effect on GDP is expressed as the percentage deviation from a baseline scenario, where population and productivity continue to grow in line with their trends. Hence, the baseline scenario of GDP shows a rising trend and GDP is significantly higher 2100 than it is today. In the **Net Zero 2050** and **Delayed Transition** scenarios, global GDP is about 2 per cent lower than the baseline scenario by 2100, while it is just over 7 per cent lower in the **Current Policies** scenario.

A source of uncertainty in the scenarios is to what extent the economic model is a good description of reality. This is because all models include simplified assumptions of reality and therefore different types of error. One way to illustrate the sensitivity of the model's assumptions is to calculate the same scenario with a set of different models. NGFS uses, for example, three different integrated assessment models. However, the difference in GDP is small between these models, as illustrated in Figure 5 (b) for the scenario **Current Policies**.

[13] The three models are REMIND-MAgPIE, MESSAGEix-GLOBIOM and GCAM.

Figure 5. Global GDP, 5(a) GDP from REMIND-MAgPIE, 5(b) GDP from three different integrated assessment models in the Current Policies scenario

Per cent



Note. The scenarios show deviations from a baseline scenario.

Source: IIASA NGFS climate scenarios.

The economic cost in terms of global GDP is relatively small in these scenarios. This is in line with results from other studies. A compilation of various studies shows a cost of around 5 per cent of global GDP at 2°C global warming and 10 per cent if global warming reaches 3°C.[14] Hence, the global GDP level would be 5–10 per cent lower in the long-term, compared to what it would otherwise have been. This should be put in relation to the fact that GDP – if the economy, for example, grows by 2.5 per cent per year – will double approximately every 30 years.[15]

At the global level, the reduction of GDP due to climate change should be manageable. However, the effect on individual countries, sectors and groups may be significantly more serious than the global average, which is important to bear in mind when assessing the impact on the economy. Furthermore, a small effect on GDP does not rule out large effects on welfare, which depends on more factors than just GDP.

4 Lower GDP effects in Sweden than globally

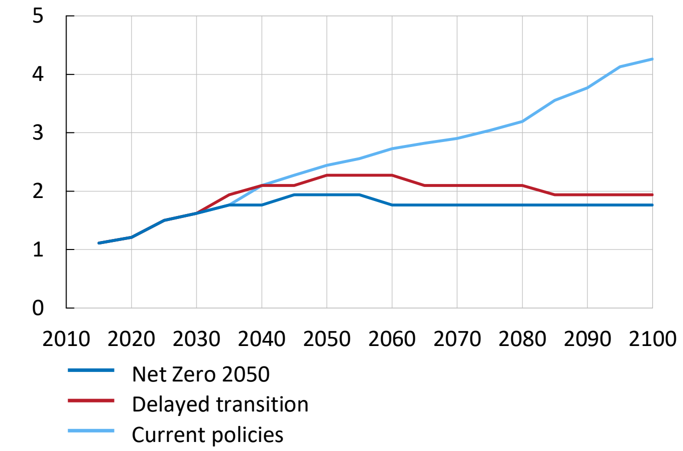
The effects of climate change vary by region and country. In Europe, for example, rainfall is decreasing in southern Europe, while it is increasing in the north. The largest temperature increases occur in southern Europe in the summer and in the Arctic region in the winter. Regarding Sweden, the average annual temperature has increased by more than the global average, which is reflected in the conditions for the scenarios. For example, in the **Current Policies** scenario, the temperature rise in Sweden is about 1°C higher than the global average in 2100, see Figure 2 and 6.

[14] See SNS (2020).

[15] See Olovsson (2020) for further references and discussion of the economic cost of climate change.

Figure 6. Temperature increases in Sweden in the scenarios

Degrees Celsius



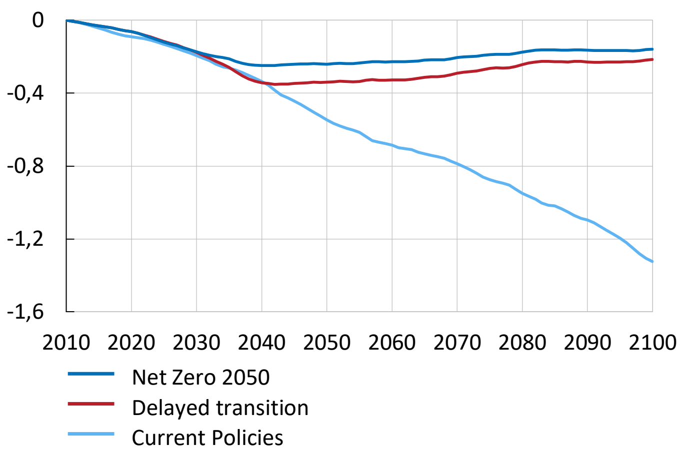
Note. Temperature increases since pre-industrial period (1850–1900).

Source: IIASA NGFS climate scenarios.

The NGFS has calculated scenarios for Swedish GDP from both the integrated assessment models and the macro model NiGEM. Figure 7 shows Swedish GDP from the integrated assessment model REMIND-MAgPIE. In the scenarios **Net Zero 2050** and **Delayed Transition**, Swedish GDP is, in principle, unchanged (around 0.2 per cent less compared to the baseline scenario in 2100). The impact on Swedish GDP is also small in the **Current Policies** scenario, GDP is around 1.3 per cent less in this case. The economic cost in terms of reduced GDP is thus less in Sweden than the global average. Moreover, the differences in Swedish GDP between the integrated assessment models are small, just as they were in the scenarios for global GDP.

Figure 7. Swedish GDP from REMIND-MAgPIE

Per cent



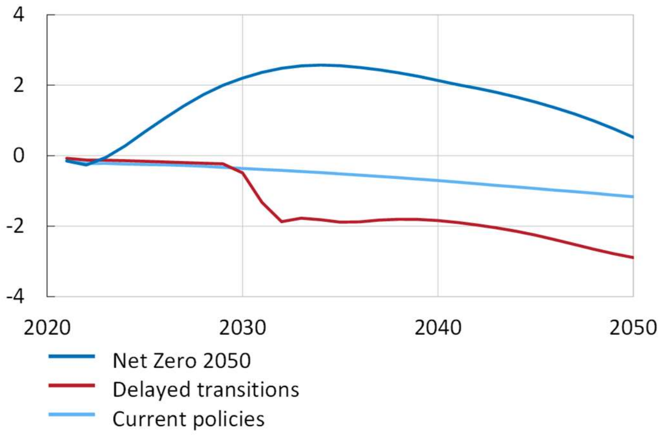
Note. The scenarios show deviations from a baseline scenario.

Source: IIASA NGFS climate scenarios.

Figure 8 shows the three scenarios for Swedish GDP according to NiGEM. In general, there are slightly greater effects on GDP in NiGEM than in the integrated assessment models. In addition, the effect is qualitatively different in the **Net Zero 2050** scenario, where GDP is in fact higher, not lower, than the baseline scenario. One reason for this has to do with fiscal policy. In NiGEM, the government's tax revenue from increased CO_2 taxes is channelled back into the economy in the form of investment, which has a positive effect on GDP compared to the integrated assessment models that omit this effect.

Figure 8. Swedish GDP from NiGEM

Per cent



Note. The scenarios show deviations from a baseline scenario.

Source: IIASA NGFS climate scenarios.

Few studies have calculated the economic cost of climate change in terms of Swedish GDP. One example, however, is the 2007 study "Sweden facing climate change – threats and opportunities", which is based on a scenario with temperature increases of 3–5°C by the 2080s, compared to 1960–1990.[16] The results show that both the cost and the revenue in terms of GDP are small and approximately cancel each other out. The total cost is estimated to be a few tenths of a per cent of GDP, in other words even less than in the **Current Policies** scenario, which would be the most comparable of the NGFS scenarios.

The small effect on Swedish GDP may have several causes. The sectors most affected by climate change – agriculture, forestry and fisheries – are relatively small in relation to GDP, and they are expected to become even smaller in the future. In Sweden and in other developed economies, the goods sector is expected to decline at the expense of the service sector, which is likely to be less sensitive to climate change. There are also effective transfer and insurance systems that can compensate sectors that are severely impacted in more developed economies. The overall economy may therefore not be as badly affected. However, Sweden is not an isolated island and is dependent on global economic developments. If climate change would severely affect the world's economies, spillover effects will most likely also affect Sweden.

[16] See SOU (2007).

A conclusion one can make from the NGFS scenarios and similar studies is that an ambitious climate policy that reduces emissions does not have to be too costly. This is also in line with results from a new study, according to which an effectively implemented climate policy – a time-varying global CO_2 tax combined with region- and generation-specific net transfers – could increase the welfare of both present and future generations by over 4 per cent.[17]

Climate change may affect inflation

Figure 9 shows the Swedish inflation rate in the three scenarios according to NiGEM. The energy price (CO_2 price) is one of the contributions to inflation in these scenarios. A higher energy price in the **Net Zero 2050** scenario than in the **Delayed Transition** scenario is one reason why inflation is higher in the first scenario. Another reason is fiscal policy. In the **Net Zero 2050** scenario, it is assumed that a higher CO_2 price generate fiscal revenues, which are recycled back into the economy (50 per cent through public investment and 50 per cent to repay public debt). The investment channel has a positive effect on GDP, but also on inflation via an increase in demand. In the **Delayed Transition** scenario, fiscal revenues from a higher CO_2 price are used to reduce income taxes, which has a lower impact on both GDP and inflation. In the **Current Policies** scenario, the CO_2 price remains unchanged and there is little impact on inflation.

In the transition to a carbon neutral economy, energy prices are likely to rise. This has a direct impact on the cost of living for households when, for example, heating costs for houses rise. However, whether a rise in the cost of living (measured by the consumer price index) also signals higher inflation depends on what happens to prices in the rest of the economy.

A rise in only the energy price is an individual price change or a so-called relative price change. This is not inflation in the true sense of the word, i.e., it is not an increase in the general price level or, to put it another way, a reduction in the value of money.[18] Monetary policy is not supposed to affect contemporary relative prices, although, in practice, this may be difficult to avoid, since some sectors are more interest rate sensitive than others.

From a monetary policy perspective, changes in relative prices are worrying to the extent that they signal a risk of a general rise or fall in prices. However, this can be difficult to determine in practice. Central banks therefore also examine other measures of inflation than the standard cost of living index to obtain further information on inflationary pressures. For example, the Riksbank examines changes in the CPIF excluding energy, which is a measure that explicitly excludes energy prices.[19]

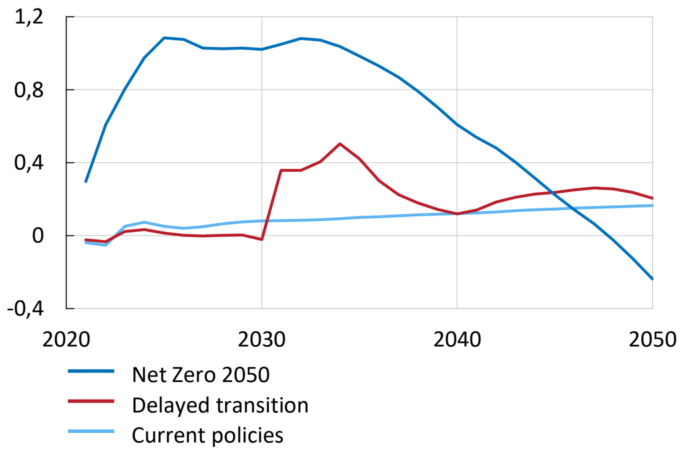
[17] See Kotlikoff et al. (2021).

[18] See Bryan (2002) for a discussion of the difference between changes in the general level of prices and a cost-of-living index.

[19] In the longer term, there is considerable uncertainty on how energy prices will develop. One important factor is technological development. A higher price drives the development of new technologies that may make it cheaper to produce fossil-free energy and may contribute to energy efficiency that will dampen demand.

Figure 9. Swedish inflation from NiGEM

Percentage points



Note. The scenarios show deviations from a baseline scenario.

Source: IIASA NGFS climate scenarios.

5 Concluding comments

The economic cost in terms of GDP is relatively small in the NGFS scenarios. The calculations include the cost of physical and transition risks, but the risk of tipping points is not included, which may entail high costs for both nature and the economy if they occur. The IPCC report from 2021 mention that tipping points cannot be excluded (high confidence). Some new research also suggest that the risk of tipping points may have been underestimated in previous studies. Among other things, the studies may have missed how tipping points can interact and reinforce each other. For example, if one tipping point is exceeded, it may increase the probability of others following via so-called domino effects.[20]

In other words, the economic cost may be greater than what NGFS's scenarios and similar studies suggest. This is something that policymakers may want to consider when they formulate climate policies. It is equivalent to taking out a fire insurance.[21] In the risk assessments, you place a greater emphasis on the risk that the house will burn down than on the most likely outcome, which is that the house will not burn down. When exposed to serious threats – at the same time as uncertainty is high – we should take out an insurance to avoid or at least reduce the consequences of the worst outcomes.[22]

From an economic point of view, climate change is the result of a market failure, i.e., the markets are not able, by themselves, to allocate the economic resources to the

[20] See Rocha et al. (2018) and Steffen et al. (2018).

[21] See Weitzman (2009), who argues that climate policy should be designed to avoid the worst outcomes.

[22] See Hassler et al. (2018).

areas where they provide the greatest benefit.[23] In the case of climate change, the market failure is due to the price of emitting CO_2 is too low. When households and firms make economic decisions that affect CO_2 emissions, they only consider their own private cost, and do not consider the cost to society as a whole. The emissions therefore become higher than what is socially efficient.

To counteract the market failure of climate change, policy measures need to make it more expensive for households and firms to emit CO_2. Moreover, it is not enough that emissions are reduced in an individual country or region; emissions need to be reduced at a global level. Global warming is due to the world's total emissions and a higher emission price that only affects part of the world risks leading to emissions only moving to other parts of the world. The policy instruments most readily available are global CO_2 taxes and emissions trading, provided that these are designed to ensure that the emission price is sufficiently high. A global agreement on a price floor for emission rights is another instrument for increasing CO_2 prices globally and thus reducing emissions.

According to most economists, a global tax on CO_2 emissions is the ideal solution.[24] This would be a relatively cheap insurance against the worst outcomes. Although many governments say they support a global CO_2 tax, it has proved difficult to agree on concrete proposals so far. Taxes are largely a national matter and are difficult to impose at a global level. However, a global price floor, which preserves some national freedom but counteracts a "race to the bottom", may fulfil a similar function.

Finally, the NGFS climate scenarios have increased our knowledge of the economic consequences of climate change. However, as new information and knowledge become available it is important to update the scenarios, as also Frank Elderson, Chair of the NGFS, has stated:[25]

With these scenarios, the NGFS provides – and intends to regularly update – an important public good for all stakeholders, public and private, to help them engage in forward-looking climate-risk analysis under a common and consistent global reference framework.

The NGFS are planning to update the scenarios by, for example, adding further sectoral granularity, improving the economic modelling of physical risks, and further exploring the role of monetary and fiscal policies.

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[24] See Olovsson (2020) and Ciccarelli and Marotta (2021).

[25] See NGFS (2021a).

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