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CLIMATE CHANGE AND LONG TERM FISCAL SUSTAINABILITY

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Climate Change and Long-term Fiscal Sustainability

Scoping Paper

Presented at the Joint 3rd OECD Paris Collaborative on Green Budgeting Expert Group Meeting & 1st Workshop of the Coalition of Finance Ministers for Climate Action on Helsinki Principle Four "Macroeconomic Management and Public Finance" on 16-17 March 2020, OECD Headquarters

This paper was generously prepared by the Swiss Finance Administration for discussion by the OECD Paris Collaborative on Green Budgeting.

It describes channels through which climate change has a fiscal impact, discusses the uncertainties that make a quantitative estimate difficult, and provides several examples of qualitative and quantitative studies that show how fiscal impacts could be integrated into official fiscal reports.

A final draft of this paper will be published in the OECD Journal of Budgeting in due course.

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Introduction

Climate change will have manifold socio-economic consequences. It will affect important economic sectors such as agriculture, energy, infrastructure and healthcare and effect changes in the supply and demand for goods and services in all sectors of the economy, with varying degrees of intensity. Increasing temperatures, rising sea levels, frequent extreme weather events and other climatic changes will affect aspects of life apart from economic activity, such as human security, health and well-being, and even culture.

In view of these socio-economic consequences, climate change is expected to affect the fiscal sustainability of government budgets in the medium and long term. Fiscal sustainability is an important policy objective for many countries, requiring a balance between tax revenues and public expenditures at national and subnational levels. For example, climate change impacts may lead to higher public expenditures for the reconstruction of infrastructure or disaster relief transfers, thereby causing an imbalance in public budgets. In addition, climate change may have adverse economic effects that reduce the tax base and thus lower tax revenues, increasing fiscal imbalances. These fiscal consequences of climate change are of special interest for governments around the globe, given that demographic change will already place a large burden on public finances in the coming decades.

For assessing the long-term fiscal sustainability of government budgets, environmental and climate-related factors will thus become more important. While the publication of long-term fiscal sustainability reports has become more widespread in recent years, they have usually tended to focus on classical forecasting issues, such as demographic change and contingent liabilities, rather than the potentially disruptive and transformative factors arising from environmental challenges. Until now, only a few countries consider climate risk in their fiscal sustainability assessments or similar fiscal reports. In Switzerland, the budgetary impact of climate change was presented in a qualitative assessment of possible impacts in the Report on the Long-Term Sustainability of Public Finances 2016 (FDF, 2016). In the UK, the Office for Budget Responsibility included a qualitative assessment of the impacts of climate change for the first time in its 2019 Fiscal Risks Report (OBR, 2019). In its last Debt Sustainability Monitor (European Commission, 2020), the European Commission discusses how the climate change dimension could be included in its debt sustainability analysis framework. In a special report, the U.S. Office of Management and Budget provides preliminary quantitative estimates of the impact of climate change in selected fields (OMB, 2016).

To identify, assess and manage longer-term sustainability and other fiscal risks prudently, governments should integrate environmental costs and benefits into medium- and longer-term fiscal planning. In the longer run, countries will also need to prepare for eroding energy-tax bases. However, there are considerable challenges to a more systematic and quantified approach to the integration of climate change risk into fiscal sustainability reporting. These include, in particular, the lack of data on quantified economic impacts and the difficulty of predicting the frequency of extreme weather events and the impacts of climate change from the rest of the world (spillovers, migration, trade etc.).

This paper was generously prepared by the Swiss Finance Administration for discussion by the OECD Paris Collaborative on Green Budgeting (PCGB). The PCGB was launched as one of the twelve commitments presented by President Macron at the One Planet Summit on 12 December 2017 as a multi-disciplinary platform for focused research and analysis. The PCGB develops concrete and practical guidance to help governments at all levels embed consideration of climate and environmental goals within their budget frameworks. It also identifies research priorities and gaps to advance the analytical and methodological groundwork for green budgeting, designs and tests pragmatic green budgeting tools and supports peer-learning and the exchange of data and best practices.

The paper builds on preliminary discussions at the second meeting of the Green Budgeting Expert Group held under the auspices of the PCGB on 29 April 2019. It was also discussed at the joint 3rd OECD Paris Collaborative on Green Budgeting Expert Group Meeting & 1st Workshop of the Coalition of Finance Ministers on Climate Action on Helsinki Principle Four "Macroeconomic Management and Public Finance" on 16-17 March 2020.

Objective and scope of the paper

This paper describes the channels through which climate change has a fiscal impact. It scopes out the revenue and expenditure risks and opportunities on the pathway towards low greenhouse gas emissions and environmentally resilient development that are relevant for budgetary sustainability. In this view, it addresses the following questions:

- How can governments better assess the budgetary implications of disruptive and transformative factors arising from mitigation of climate change?
- How can governments improve the assessment and management of fiscal risk to adopt timely policy responses to make public finances fiscally sustainable over the long run in the context of climate change and other environmental challenges?

This paper articulates current knowledge. It does not provide new quantitative results. Chapter 3 outlines the main channels by which climate change has an impact on i) the environment, ii) the economy and iii) the budget. It also discusses the sources of uncertainties that make it difficult to quantify the fiscal impact of climate change. Chapter 4 reviews the existing literature focusing on the long-term fiscal impact of climate change. Chapter 5 provides preliminary conclusions. Annex A. describes the Swiss case in more detail.

Channels of the impact of climate change and sources of uncertainty

Whereas it is clear that climate change will have an impact, the global and long-term nature of the process and its complexity make its amplitude and timing uncertain. This chapter discusses the sources of these uncertainties as well as the channels through which greenhouse gas (GHG) emissions have an impact on the environment, the economy, and finally the budget.

3.1. Greenhouse gas (GHG) emissions

We will illustrate the issue of GHG emissions through the example of the main anthropogenic GHG: CO_2 (there are also other greenhouse gases, e.g. water vapour, methane). According to the Kaya identity (Kaya et Yokoburi, 1997):

$$CO_2\ emissions = population * \frac{GDP}{Population} * \frac{Energy}{GDP} * \frac{C0_2\ emissions}{Energy}$$

The future path of GHG emissions will depend on demography, economic development and technology, lifestyle and behaviour (IPCC, 2014). Despite international efforts, CO_2 emissions have been increasing. The figure below for the last four decades shows that while the energy intensity of GDP has decreased in every decade and carbon intensity of energy has decreased in most decades, the impact of reducing the carbon intensity of GDP has been more than compensated for by the increase in population and GDP per capita. Scenarios of future emissions can be computed on the basis of scenarios for the four factors.

Figure 1. Decomposition of changes in CO2 emissions according to the Kaya identity

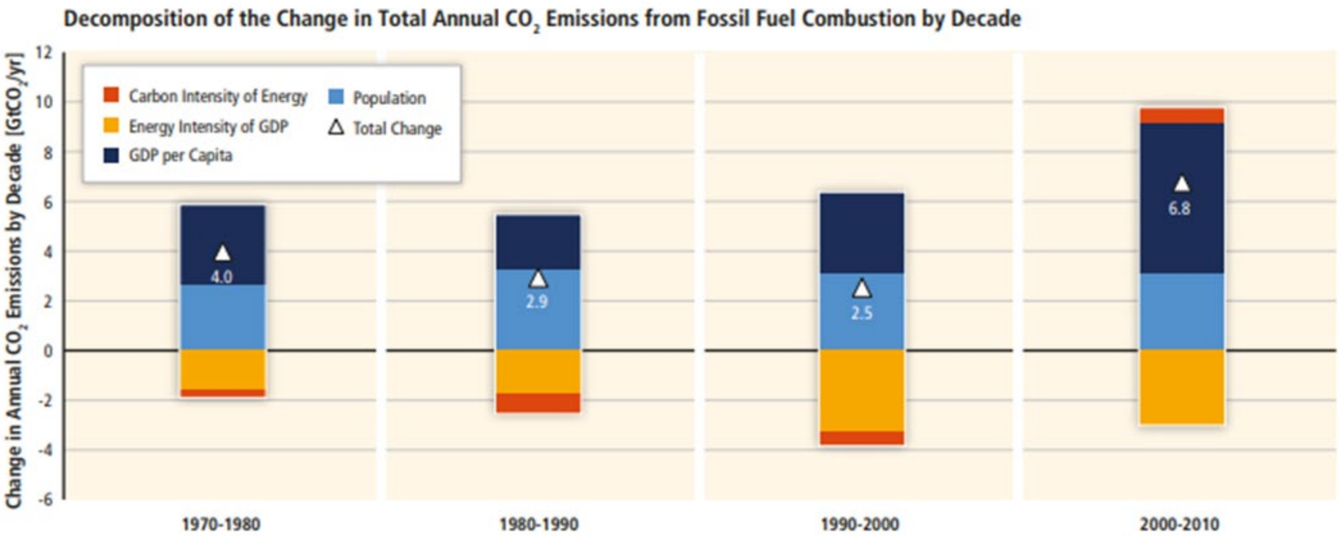


Figure SPM.3| Decomposition of the change in total annual CO_2 emissions from fossil fuel combustion by decade and four driving factors: population, income (GDP) per capita, energy intensity of GDP and carbon intensity of energy. The bar segments show the changes associated with each factor alone, holding the respective other factors constant. Total emissions changes are indicated by a triangle. The change in emissions over each decade is measured in gigatonnes of CO_2 per year [$GtCO_2$/yr]; income is converted into common units using purchasing power parities. [Figure 1.7]

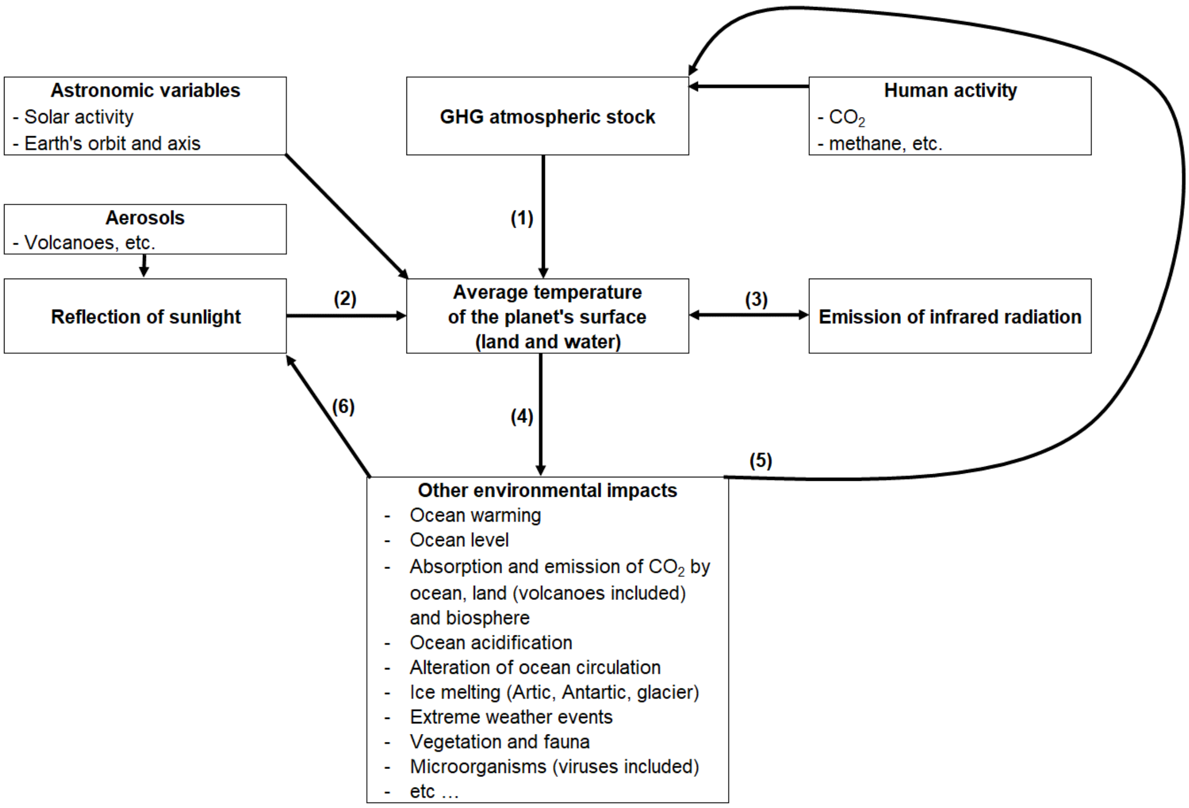
Source: IPCC (2014)

Technology as well as lifestyle and behaviour are influenced by mitigation policies (i.e. policies to reduce climate change), which in turn depend on available technologies, opportunity costs (in terms of consumption, as well as resources diverted from efforts to meet other challenges), preferences, degree of voluntarism and international coordination. Technological progress can contribute to the mitigation of GHG emissions by increasing efficiency (e.g. energy conservation) or providing alternative technologies that avoid the use of GHGs or GHGs-producing processes like combustion (e.g. renewable energy or nuclear fusion). It can also deliver technologies that prevent the diffusion of GHGs (e.g. carbon capture at source in exhaust gases), permanently remove some GHGs from the earth's atmosphere (by expanding forests as carbon sinks, using biomass to generate energy while capturing and storing the resulting CO_2, or through artificial carbon capture and storage) or, more controversially, counteract climate change by other geoengineering options (e.g. solar radiation management). Some of these alternatives may generate their own environmental risks. For example, there is currently a trade-off between climate change and risks associated with nuclear fission. The risks associated with new technologies, like geoengineering, are especially difficult to assess. It cannot be excluded that the fanciest cures may be worse than the disease. These and other potential trade-offs between climate policy and other goals such as affordability, competitiveness and jobs may constrain the ambition of climate action (OECD, 2019b).

3.2. Environmental impact of a given quantity of GHG emissions

In a first step, GHGs affect the environment through the greenhouse effect involving well-known and well-proven physical effects (reflection, absorption and emission of electromagnetic radiation). This however generates in a second step a cascade of other effects, including positive and negative feedbacks. The complexity of the global Earth system, as well as time lags and non-linearities make it difficult to assess the magnitude of these feedback loops and even to ensure that no major channel has been overlooked. Whereas there is a scientific consensus that a rapid climate change caused by humans is ongoing, its ultimate environmental impacts are largely unknown.

Figure 2. Environmental impact of GHG



Source: Authors

The different channels depicted in Figure 2 can be described as follows:

(1) Greenhouse effect

GHGs act like a barrier reducing the emission of infrared radiation by the Earth. This increases the Earth's temperature.

(2) Reflection of sunlight
Part of the light of the sun is simply reflected by the Earth and thus does not heat the Earth.

(3) Additional infrared emissions
When the Earth's surface (or its atmosphere) is warmer it radiates more energy into space, thus limiting global warming.

(4) Other environmental impacts generated by an increase in GHGs and temperature
The absorption of a large part of heat by oceans reduces warming on land. Since the volume of water increases when water gets warmer, this also raises the level of oceans. Melting of land-based ice also contributes to raising the level of oceans. Ice melting interferes with the global ocean-circulation system. Global warming increases the intensity and frequency of extreme weather events. Increased temperature and related consequences have an impact on vegetation and fauna. It also has an impact on microorganisms. Viruses for example may spread to new territories or emerge from the permafrost where they were frozen.

(5) Feedbacks to GHG emissions
GHGs induce global warming, which has environmental impacts that in turn can change the density of GHGs in the atmosphere. Oceans capture CO_2, which attenuates the CO_2 increase in the atmosphere but also acidifies the oceans. However, warm water holds less CO_2 than cold water. As temperatures of oceans rise, they will become less able to absorb new CO_2. The warming of oceans increases evaporation generating water vapour, a GHG contributing to global warming. Global warming accelerates the release of GHGs from permafrost regions of the Arctic. There is also a deep carbon cycle involving the Earth's mantle and volcanoes. Understanding the carbon cycles is especially crucial but complex since carbon interacts not only with inanimate matter (like oceans and rocks), but also with living organisms.

(6) Feed-backs through sunlight reflection
Evaporation from the oceans generates clouds (this process also involves aerosols to form droplets) that reflect some incident solar radiation back into space. The decrease of the polar ice on the other hand reduces reflection of solar radiation since white ice reflects sunlight particularly well. Expanding forests takes up CO_2 from the atmosphere, but reduces sunlight reflection when trees with dark leaves cover light-coloured ground or snow.

This short description is far from exhaustive, but illustrates the complexity of the issue. It is easy to miss some important feedbacks, be they positive (amplifying climate change) or negative (diminishing climate change). The magnitude of many of these effects is difficult to quantify. How big will the impact on extreme weather events be? On ecosystems? What about the spread of infectious diseases? How much GHG is needed to significantly slow down the ocean circulation? There may be tipping-points inducing big and (quasi-) irreversible changes in the climate system and beyond. Given the limitations of our knowledge, massive catastrophic events cannot be excluded.

A way to check models to see if they take into account all important feedbacks is to compare predictions of climate models and actual climate evolution. Hausfather et al. (2019) find that "climate models published over the past five decades were generally quite accurate in predicting global warming in the years after publication, particularly when accounting for differences between modelled and actual changes in atmospheric CO_2 and other climate drivers". Feedbacks loops, however, can take a long time to occur. Because of such time lags it is not self-evident that a model that has forecasted well for a few decades will do so well for a few centuries.

Uncertainty about lags make it also difficult to forecast the timing of the environmental impact. Furthermore, impacts can be non-linear: doubling the cause may more than double the effect (or less). A way to check climate models for lags and nonlinearities is to use them for "predicting" the climate of the past. It appears that increased CO_2 emissions are a key driver of recent warming. The success of a model in "predicting" the past, however, does not have the same scientific status as predicting the future: what matters is not only if the model has predicted the past well, but the extent to which it can be proven to be false. All these uncertainties become larger the farther the time horizon. Moreover, uncertainties are larger at the local or national level (where adaptation measures are to be taken) than at the world level.

Long-term models are necessary to compute, for example, the carbon budget: the maximum cumulated future GHG emissions compatible with staying permanently below a given level of global warming. The carbon budget is crucial for defining mitigation pathways (except if future negative net emissions can counterbalance the excess over the carbon budget). According to Hausfather (2018), the remaining carbon budget from 2018 onwards is 580 $GtCO_2$ for a 50% chance of keeping warming below 1.5°C (about 14 years of global emissions at current rates). The fact that this is more than double the previous estimation illustrates the uncertainty.

3.3. How environmental impact and mitigation policies translate into economic impact

The impact of climate change on the economy has two components: i) “physical risks” i.e. the consequences of the environmental impact and ii) “transition risks” i.e. the consequences of policies aimed at mitigating climate change (Batten, 2018).

Consequences of the environmental impact

Increases in the global mean surface temperature affect processes involved in desertification, land degradation and food security. Changes in these processes drive risks to food systems, livelihoods, infrastructure, the value of land, and human and ecosystem health (IPCC, 2019). Negative impacts also include, for example: loss of labour productivity due to extreme heat and more generally the impact on healthcare, damage from sea level rise and extreme weather events, premature fatalities from extreme weather events, loss of ecosystem services, reduced productive investments caused by uncertainty about climate events (and by diversion of resources toward climate-related investments as described below).

It is important to be aware of positive as well as negative impacts. Positive impacts are more likely in cold regions, reducing for example energy use for heating, facilitating agriculture and opening navigational opportunities in the Arctic Ocean (which in turn will have a negative impact on countries on current routes). However, the overall net impact will be negative, since plants, animals, humans and our civilization (location of most of the largest cities near the sea, etc.) have adapted to the current climate, and rapid changes are costly.

The economic damage induced by a given environmental impact will depend on the state of the economy. Nobody knows what the next century’s economy will look like and if most sectors will be climate-sensitive or not. A simplistic approach would be to assume that the structure of the future economy will be the same as today’s and proceed to evaluate the impact of climate change assuming no adaptation.

A more elaborate assumption is that the structure of the economy would not change in the absence of climate change, but will adapt to climate change. Places with warmer climates can be used to evaluate possible adaptations. The economies in such places may, however, differ for reasons not related to climate (e.g. institutions). Looking at warmer years in the same place reduces the number of factors unrelated to climate. However, this approach does not account for adaptation since a country does not adapt to a warmer year as well as a warmer country is adapted to its own average temperature. Moreover, warmer places and times may differ from a global warming where extreme weather events are more frequent.

The evolution of the structure of the economy unrelated to climate change should ideally also be taken into account. For example, there might be changes in the way food is produced (what will be the market-share of artificial meat or of indoor vertical farming systems?) and digitalisation will spread. This may make the economy more sensitive or less sensitive to climate change. It is for this future economy that the impact of climate change should be computed (taking adaptation into account).

The reaction of the economy to climate change may not be merely adaptation. Climate change could have an economic impact through its political impact: climate-induced conflicts might for example weaken the economy. Some market failures other than negative externalities may interact with climate change (see an example below related to mitigation policies). A key issue is whether climate change will reduce merely the GDP level or also its rate of growth. If present, the latter effect would dominate in the long run. Another issue is whether the function relating GHG emissions to economic damages should allow for discontinuities related to tipping points.

Impact of mitigation and adaptation policies

Although mitigation policies will reduce GHG emissions and thus their environmental and economic impact, they will generate their own costs, which must be added to the cost arising from the environmental impact. Mitigation policies are indeed costly. Countries able to develop and export products needed to reduce GHG emissions may profit from the change. Fossil-fuel-rich countries, especially if their economy is not well diversified, will suffer from a reduction of their wealth as the price of fossil energy decreases or part of their reserves are stranded. The reverse is true for countries holding material critical for renewable energy. Stranded assets may be bad news even for countries suffering from a resource curse since inertia may extend the curse after the resources have lost their value. While mitigation policies (e.g.: geoengineering and nuclear energy) present their own costs and sometimes their own risks (that put nuclear energy in another category than renewable energy)[1], they also provide side benefits such as reduced air pollution and associated health problems. Geoengineering may be too risky even in the long run. If mitigation objectives cannot be wholly attained through reducing carbon intensity of energy and energy intensity of GDP, GDP will have to be reduced or the objectives adjusted.

From a broader perspective, mitigation and adaptation policies divert resources toward climate-related production (except in cases where these measures would be profitable even in absence of climate change). This may not be reflected in GDP as production aiming at limiting climate change or compensating for its effects contributes to GDP. However, it modifies the structure of the economy toward climate-related production that would not have been necessary in the absence of climate-change issues to the detriment of other production (including investments that would have enhanced productivity). Moreover, these policies require the use of energy even if mitigation policies eventually reduce the need for energy.

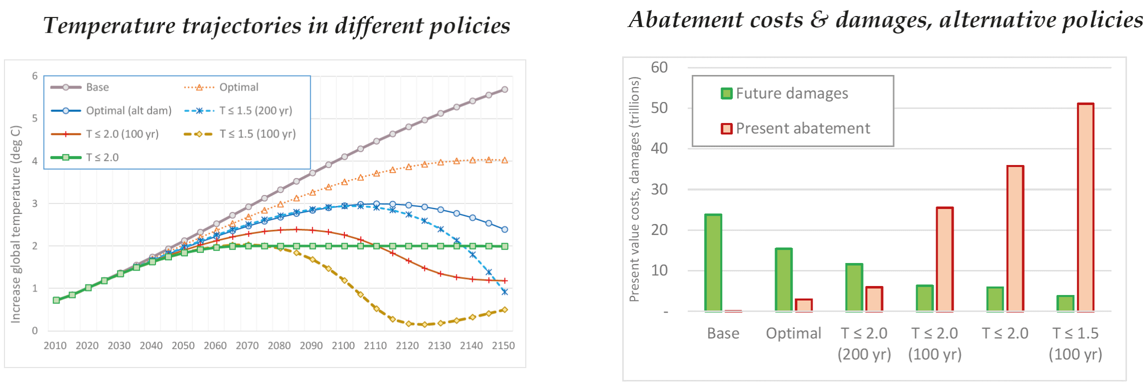
Some market failures may impede mitigation. As a global public good, its provision is hampered by the free-rider problem among countries. The principal-agent problem may be an obstacle at the country level. Other market failures may magnify the damage caused by successful mitigation. As argued for example by Cust et al. (2017), to limit the increase in global temperature to 2 degrees Celsius, more than two-thirds of currently known reserves must remain in the ground rather than be burned (neglecting mitigation by carbon capture). These reserves are currently valued on the stock market and will lose all value if a 2 degree Celsius mitigation is successful. If this is not sufficiently anticipated due to some market failures such as imperfect information or myopia, this will be a shock to the financial market. This could generate a financial crisis that would magnify the negative economic impact of climate change. This also means that when commitment to mitigate climate change becomes credible, there will be a run to sell fossil energy at discount prices rather than not sell it at all. Lower prices for fossil energy will make climate-change mitigation more difficult and require even more voluntarist mitigation policies.

The extent to which mitigation policies will be implemented depends on how much these market failures impede, but also on the expected economic impact of climate change. It also depends on value judgments about fairness and risks. What discount rate should be used to compare current costs of public mitigation policies and the future benefits (loss-reduction) they will generate? Should it include a pure preference for the present (unrelated to increased wealth in the future)? Should the discount rate be equal to the interest rate or much lower (this issue is less acute at a time of low interest rates)? How much redistribution across time is judged fair (especially if future generations will be richer than current ones)? What degree of risk aversion should be used?

Quantitative scenarios

There are many different estimates of the economic cost of climate change. Nordhaus presented the following slides in his Nobel Prize lecture (Nordhaus, 2018b).

Figure 3. Temperature and costs for various policies



Source: Nordhaus (2018b)

The *Base* scenario is business-as-usual leading to a rise in global temperature of about 4°C above preindustrial temperature by 2100 (currently already at about 0.9°C above preindustrial temperature).[2] The *Optimal* scenario (minimum cost) leads to a temperature increase of about 3.5°C by 2100. The $T \leq 2.0$ scenario which limits temperature rise to 2°C implies smaller damages but much higher abatement costs so that the sum of damages and abatement costs is higher than in the business-as-usual scenario (abatement alone in the $T \leq 2.0$ scenario is already larger than future damages in the business-as-usual scenario). The Paris Agreement is even more ambitious since it aims at holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. The $T \leq 2.0\ (200\ yr)$ scenario where the temperature is equal to 2.0°C on average over 200 years (and can thus temporally overshoot the 2°C limit) engenders smaller damages although its overall cost is fairly close to optimal.

The damages and abatement-cost values in the above figure are, however, present values. It is debatable which discount rate should be used to compute them. Nordhaus tends to use a high discount rate that reduces the weight of future damages relative to previous abatement costs. There is also a lot of uncertainty. The uncertainty is presumably much greater about future damages than about present abatement. Adding a very uncertain damage cost to a fairly certain abatement cost can be misleading. Moreover, many authors argue that worse-case scenarios are more relevant than best-guess estimates since the goal should be to avoid a catastrophic scenario (see the discussion on “fat-tail” in section 3.5 below).

Other models give other results:

According to Stern (2007): “Using the results from formal economic models, the Review estimates that if we don't act, the overall costs and risks of climate change will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, the estimates of damage could rise to 20% of GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year.”

The IPCC (2018) special report on the impacts of global warming of 1.5°C finds that limiting global warming to 1.5°C in comparison to 2°C would reduce challenging impacts on ecosystems, human health and well-being. For instance, by 2100, global sea level rise would be 10 cm lower with global warming of 1.5°C compared to 2°C. The likelihood of an Arctic Ocean free of sea ice in summer would be once per century with global warming of 1.5°C, compared with at least once per decade with 2°C. Coral reefs would decline by 70-90 percent with global warming of 1.5°C, whereas virtually all (> 99 percent) would be lost with 2°C. Limiting global warming to 1.5°C is possible, but would require rapid and far-reaching measures.

When assessing the importance of the impact of climate change on the economy, it is useful to compute the yearly change of GDP growth that would be equivalent. For example, an annual growth rate of GDP of 1% leads to a multiplication of GDP by a factor 2.2 between 2020 and 2100. If climate change leads to a reduction of the level of the GDP by 10% in 2100 relative to the case without climate change, the GDP will be multiplied by a factor 2 instead of 2.2, which means an annual growth rate of 0.87% instead of 1%. Since many other factors could have an impact of 0.13% on the annual growth rate, such an impact would not be as considerable as it may first appear.

3.4. How economic impact translates into fiscal impact

Assuming the economic impact of climate change is known, what will the fiscal impact be? For the purpose of this scoping paper, the three functions of the state according to Musgrave are considered: resource allocation, redistribution and stabilisation. Climate change can make these roles more important. This is especially the case for the allocation role since increased awareness of environmental externalities raises the importance of this role that is justified by market failures. While this is the predominant impact there may also be an increased role for redistribution if mitigation policies make basic goods and services that represent a disproportional share of low income households more expensive. It can also not be excluded that mitigation policies and climate change may increase economic instability and thus increase the need for stabilisation. In order to carry out its functions, the state needs tax revenues. This paper will discuss separately how climate change can affect these tax revenues.

Allocation

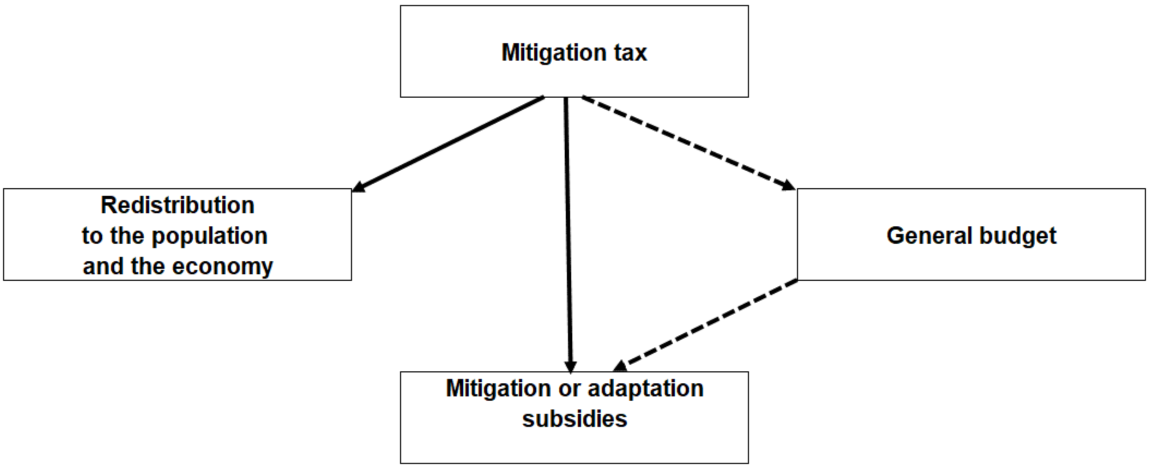
The allocation function is closely related to market failures: the state intervenes in order to compensate for market failures and to provide efficient allocation of resources. Climate change means that environmental costs (a negative externality) are higher than previously believed. This will increase the allocative role of the state. It is useful to distinguish between mitigation policies and adaptation policies as they function differently and their timing may differ.

Mitigation policies

Because of market failures (public goods and negative externalities in particular), private agents do not spontaneously choose the efficient level of mitigation. The importance of these market failures makes state intervention necessary. Mitigation policies may take many forms. Some of them, like taxes and subsidies (and public guarantees to some extent) are fiscal instruments as they affect the revenue or expenditure side of the public budget. It is possible to limit interactions with the rest of the budget. They are market-based instruments that, like emissions-trading systems, influence actors' behaviour by changing their economic incentives. Other instruments, like regulation prohibiting inefficient technologies change behaviour by command and control. Their direct effect on the budget is marginal. Different instruments can be substitutes. If, for example, the state makes the use of an efficient technology compulsory, it does not need to subsidise it: the inhabitants will bear the cost, but this will not be reflected in public expenditures. Since there is some degree of substitutability between different instruments that are differently related to the budget, it is necessary to know the structure of mitigation policies to assess their overall fiscal impact. Instruments can also be complementary. This is for example the case when an incentive tax internalises environmental costs whereas regulations deal with a principal-agent problem. The challenge is to find the optimal policy mix, taking not only GDP growth into account, but also equity issues (see below).

Mitigation taxes (like a CO_2-tax)[3] do not feed into the general budget if their revenues are redistributed as cash to the population and the economy (with no corresponding obligations for the beneficiaries) or used to finance subsidies for mitigation or adaptation. These taxes have the desired incentive impact independently of how their revenues are used. Subsidies can be separated from the budget if they are wholly financed by mitigation taxes. In these cases, mitigation taxes and mitigation subsidies do not directly interact with the general budget (or the rest of the budget). A CO_2-tax whose revenue is entirely redistributed is an incentive tax: a very different kind of tax from ones feeding into the general budget. This distinction is not merely semantic. An incentive tax is more acceptable than an ordinary tax when the public cares about climate change but does not want the government to increase its budget for other purposes. A pure incentive CO_2-tax functions as if each inhabitant had been granted the same exchangeable CO_2 allowance.

Figure 4. Mitigation taxes and subsidies and their interaction with the general budget



Note: Mitigation taxes and mitigation subsidies directly interact with the general budget only if money flows through dotted arrows.
Source: Authors

Climate mitigation costs have fallen sharply in recent years, thanks to falling costs for renewables and electric mobility. Moreover, climate mitigation has substantial, mostly local, benefits for well-being beyond the climate (for example lower air pollution). See for example OECD (2019b) for a discussion of an approach moving beyond GDP and focusing on well-being.

The cost of a mitigation policy depends on its foreseeability as sudden changes may make some assets unusable. There is, for example, a cost related to closing a coal-fired power station for mitigation purposes while it is still far from the end of its life cycle. Initiating mitigation policies soon, in particular concerning the construction of long-lived plants and buildings, would limit their ultimate cost.

Several countries are aiming at carbon neutrality by 2050. For some indications about how this goal could be achieved, see for example European Commission (2018b) and Committee on Climate Change (2019).

Adaptation policies

Adaptation is the process of adjustment to actual or expected climate change and its effects. It includes both local preventive measures (i.e. other than reducing GHG emissions, for example investments in construction protecting infrastructures) and remedial measures (post-disaster relief and reconstruction). A choice has to be made on the timing and on the optimal mix between local preventive measures and remedial measures. The cost of climate-change adaptation can potentially threaten fiscal stability, especially in exposed poor countries.

Adaptation has a fiscal impact through public expenditures (preventive measures increase public expenditures initially but reduce future expenditures for remedial measures), but also through tax revenues (as it prevents damages that may reduce economic activity, adaptation tends to preserve future fiscal revenues). Estimating the costs of adaptation is challenging because it often (although not always) depends on extreme weather events, for which it is difficult to quantify the increase in frequency and intensity that climate change will be responsible for. These costs depend on the magnitude of climate change, on which adaptation measures are taken and on their timing. As global warming has already begun, some amount of adaptation is already necessary. In some cases, like reduced costs of heating of public buildings, adaptation can reduce public expenditures.

Some costs have cross-border fiscal spillovers. Low-income countries may for example need international assistance to finance part of their adaptation policies or climate refugees may need support.

An important issue in designing adaptation policies is the question of which part of adaptation will be financed by the state (for example for protecting and repairing public infrastructures, which, according to OECD, 2019a, is the main cost associated with natural disasters for governments) and which part will be paid by the private agents (either by owners or their insurances).[4] Here again, different instruments may be substitutes. For example, insurance by the state (a fiscal instrument) versus mandatory private insurance (a regulation) or other regulatory measures such as building requirements and land-use regulation. Restrictions on land-use may have an opportunity cost that will feed back to lower fiscal revenues but will also reduce future damage or future costs of adaptation.

The choice of the optimal mix between adaptation and mitigation is distorted as mitigation has a global impact riddle with the free-rider problematic (although it also provides local benefits), whereas adaptation is local with no or few international externalities. At a local level, climate change is exogenous, and the issue is to choose adaptation optimally given expectations about climate change.

Like taxes, compliance costs of regulations are compulsory. This may be a rationale for introducing a regulatory budget analogue to a fiscal budget. Since, as do taxes, the compliance costs of mitigation and adaptation regulations reduce how much the population can spend freely, it may be relevant to account not only for fiscal costs, but also for regulatory costs. Green budgeting could even be misleading if limited to the fiscal budget, since the same total compulsory cost would appear higher in countries focusing on fiscal instruments rather than on regulations. This would be particularly perverse since fiscal instruments tend to be more efficient, and thus less costly, than regulation. On the other hand, if costs are used as a proxy for commitment, then a high regulatory budget could give the false impression that a country is very active although it is inefficient and could do more with less if it used more fiscal instruments and less regulation. In any case, quantifying the fiscal impact seems to be enough of a challenge without immediately adding the regulatory impact. Moreover, it is relevant to study the fiscal impact (rather than the total costs of mitigation and adaptation) for assessing fiscal sustainability.

Redistribution

Goods and services that are currently GHG-intensive will be made more expensive by mitigation policies. Heating and air-conditioning will become more expensive. Rent will become more expensive than in the past because the additional cost of energy efficiency and renewable energy tend not to compensate for the gain on the fossil energy bill (at least in the short term). Transportation will become more expensive too. In countries where those goods and services are disproportionally consumed by low-income households, mitigation policies will increase inequalities through the expenditure side. This happens independently of whether the mitigation policy is centred on taxes or regulations. The state will thus have to do more redistribution if it want to prevent climate change from increasing inequality.

In countries where high-income households tend to spend a smaller part of their income than low-income households for GHG-intensive consumption, taxing negative externalities will be regressive.[5] Replacing (part of) a current tax by a tax on climate externalities makes the tax system more regressive if the tax on climate externalities is more regressive than the replaced tax. Lump sum redistribution of the entire revenue earned from the tax on climate externalities would, however, make the system more progressive.[6] On the other hand, reducing other taxes and their distortions would generate more economic growth. Depending on the progressivity of the reduced taxes, there might be an efficiency/equity trade-off.

Low-income households disproportionally tend to live in more polluted areas and thus tend to profit disproportionally from co-benefits of mitigation such as cleaner air. The fact that the polluter may be poor should not be a rationale for making pollution cheap. Instead of subsidising energy use or refraining from taxing pollution, other instruments that respect the polluter-pays principle should be used to deal with equity issues, such as redistributing the revenue of taxes on pollution or increasing the scale of other redistribution tools. Other example: addressing in advance the potential impacts on the affordability of transport from increased fuel prices through targeted compensatory measures or investments in public transport infrastructure, makes such price increases more effective and acceptable by low-income households (OECD, 2019b).

Stabilisation

Climate change may increase the need for macroeconomic stabilization policies. If so, fiscal policy might be involved, especially if the current low or negative interest rates that reduce the scope for monetary policy persist.

Since climate change is a long-term process whereas macroeconomic stabilisation policies concern short-term fluctuations, climate change should not increase the need for such policies. An exception may be if extreme weather events become a very important source of shocks. However, if prior procrastination or new information causes extreme mitigation policies to be implemented abruptly, the sudden reduction of fossil-energy availability could generate a crisis. Even in case of a shock, it will differ in important ways from the oil crises in the 1970s. For example, if the increased price of fossil energy is due to increased CO_2-taxes rather than an increase in the market price of the fuel, the money will stay in the country and can thus more easily be recycled within the economy.

As discussed above, mitigation will strand some assets. This may threaten financial stability. Carbon bubble risk is a major reason why central banks, regulators and supervisors are concerned about climate change. The challenges that climate change poses include what BIS (2020) calls "green swan" risks: potentially extremely financially disruptive events that could be behind the next systemic financial crisis.

Independently of analogues to oil shocks, mitigation policies could function as a New Deal and have a positive economic impact in countries suffering from high unemployment (this could be the case of the European Green Deal in countries where unemployment is high). A long-term structural change is not the best way to deal with a short-term recession since fiscal stimulus should stop after the recession is over. Part of the resources left unemployed during a recession could, however, be used to accelerate the transition to a climate-compatible economy. This transition should already take place now, but it would be useful to be ready to accelerate it during the next recession, thus gaining a macroeconomic-stabilization benefit in addition to the environmental benefit.

Impact on tax revenues

Replacing distortive taxes by taxes such as a tax on carbon that reduce a pre-existing distortion (negative externalities) may make the tax system less distortive. This reduction of the overall economic costs associated with the tax system is called the “second dividend” of the environmental tax (the first one being the reduction of environmental damages). There may, however, be an equity issue. As discussed above, a tax on carbon is regressive in countries where high-income households tend to spend a smaller part of their revenue than low-income households for GHG intensive consumption. Replacing a distortive tax by a tax on carbon will be regressive, except if the replaced tax is even more regressive than the tax on carbon.

The following formula clarifies the impact of climate change on tax revenues.

$$\frac{Tax\ revenues}{population} = \frac{Tax\ revenues}{GDP} * \frac{GDP}{Workers} * \frac{Workers}{Population}$$

Climate change can in principle modify the average tax revenues per capita by modifying the average tax rate (Tax revenues / GDP), the productivity of labour (GDP/Workers) or the unemployment rate (through the term “Workers/Population”).

The tax system is made up of various specific taxes collected from different tax bases with their specific tax rate (or their tax-rate schedule). Even if all specific tax rates remain constant, the average tax rate may change as the structure of the economy and thus the various tax bases change. Tax on fossil energy will for example yield less revenue as consumption of fossil energy diminishes in response to higher taxes, other policies, technological improvements or changing preferences. OECD and ITF (2019) has, for example, studied the case for Slovenia. Revenues from taxes on motor oil will fall as the share of electric vehicles increases (except if the overall number of vehicles grows quickly enough for the stock of motor-oil vehicles to grow despite reduced market share, as may happen in developing and emerging economies). This problem may hit many countries fairly soon. Mobility pricing could be a solution. It would be of interest also, independently of climate change, to manage traffic congestion.

The two other terms of the formula reflect economic impacts discussed above. In particular, climate change could modify labour productivity through various channels. Uncomfortably high temperatures may reduce workers’ productivity (adaptation through air conditioning can reduce the weight of this channel). Resources that could have been invested in increasing labour productivity might be diverted to climate change mitigation or adaptation. Crop yields depend on temperature. Stranded fossil energy will impact the value produced per worker who switches to less profitable sectors, at least as long as the economy has not adapted its structures. If the reduction in carbon intensity of GDP is not sufficient, then it may be necessary to reduce GDP to attain CO_2-emissions targets.

What will be the impact of climate change on unemployment? It may increase frictional unemployment as the structure of the economy changes (e.g. retraining coal workers to become solar panel installers). The size of this effect depends on how rapid the change is. In a well-functioning economy, this would be the sole impact of climate change on unemployment. This basic assessment should, however, be qualified. Firstly, when a country rapidly introduces more stringent mitigation policies than in other countries, this can handicap its exporters and may generate unemployment (as long as the exchange rate does not adjust or labour is not reallocated to other sectors). This country may, however, also develop expertise that puts it in a pole position for exports in a growing green sector. Secondly, consider a country where unemployment is already high in the absence of climate change. This unemployment is likely due to market failures or some side effects of government policies. The first best would be to deal with these causes. But if this is not possible (and a currently long-lasting high unemployment level suggests that it is difficult), then the question arises whether the interaction between these causes and climate change could magnify unemployment.

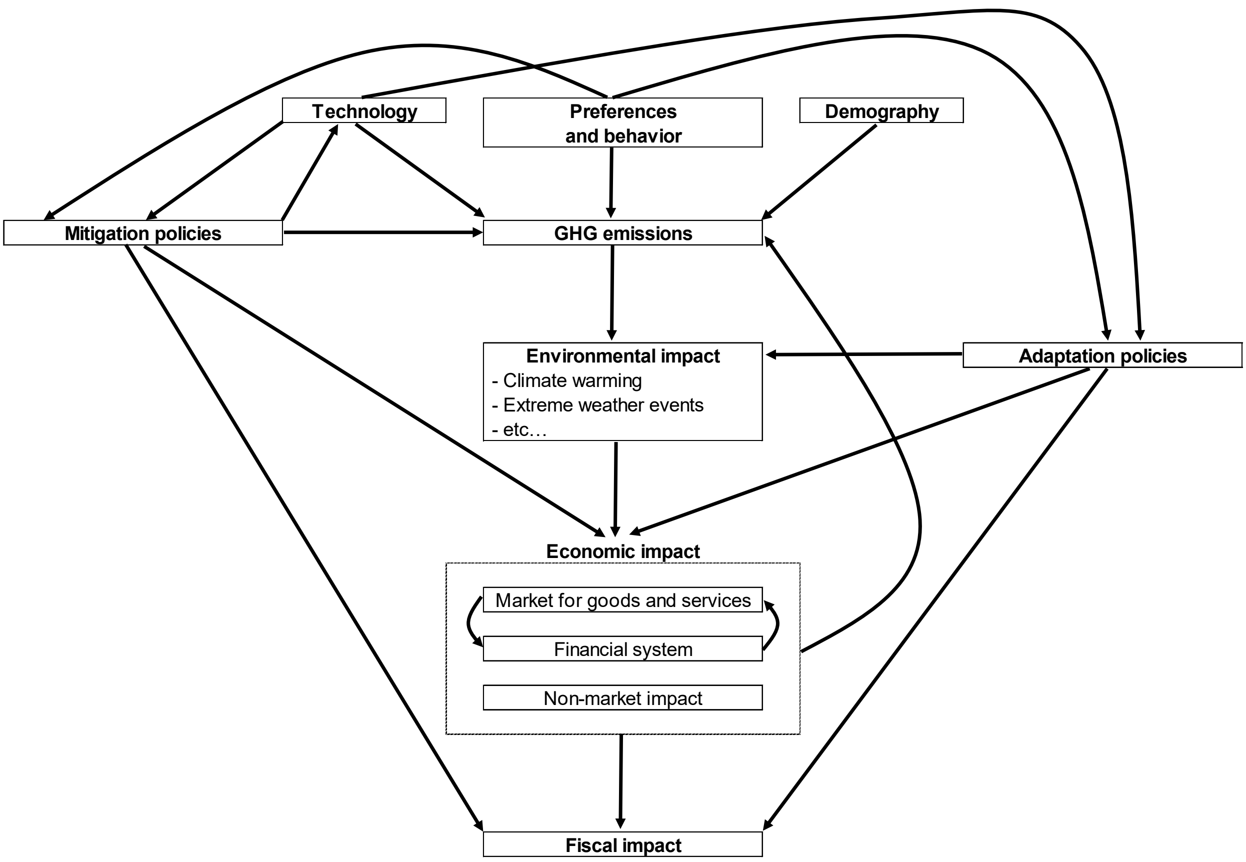
An important point is missing in this discussion. Since GDP does not take harm to the environment into account, it is a poor metric for the economic impact of climate change. The work done for mitigation and adaptation contributes to the GDP and will be taxed. This is why the fiscal cost of climate change may be more apparent on the public expenditure side than on the fiscal revenue side.

Non-market impacts

Climate change can affect the welfare of people not only through goods or services, but also directly (welfare costs of mortality, pain and suffering linked to illness, aesthetic cost of the loss of biodiversity or glaciers, etc.). These non-market impacts are particularly difficult to quantify since they have no observable price. They may be omitted when evaluating the fiscal impact , as long as they do not have a fiscal impact. This is probably the sole dimension in which quantification is less uncertain for the fiscal impact than for the economic impact.

The following figure summarizes the links between GHG emissions (Section 3.1), environmental impact (Section 3.2), economic impact (Section3.3) and fiscal impact (Section 3.4).

Figure 5. Impact of climate change (channels)



Source: Authors

3.5. Dealing with uncertainty

Except for the possibility of omitting some non-market impacts, the quantification of the fiscal impact adds a new level of uncertainty in addition to the uncertainties related to the path of GHG emissions and how these emissions translate into environmental and economic impacts. Key questions are how to deal with such a high degree of uncertainty, and what degree of certainty is necessary for which policy decision?[7] The paper focus here on two questions:

i) is uncertainty a rationale for less or for more aggressive policies,

ii) what information do we need to assess the impact of climate change on fiscal sustainability?

Should uncertainty make policies against climate change be less or more aggressive?

Mitigation

Should policies against climate change be less or more aggressive because of uncertainty about future available technologies, economic growth and the impact of climate change? With regards to mitigation policies, an argument for a less aggressive or "wait-and-see" approach is that technologies may become available that allow to mitigate climate change at lower cost. They may even be able to reduce the stock of GHGs in the atmosphere (capture and storage). In this extreme case, the issue would be fundamentally modified, as climate change would become reversible. Nevertheless, there is no guarantee about future innovations, although public policies could support them. If this technological progress is not sufficiently strong, then climate change will indeed be irreversible and the GHGs emitted during the wait-and-see period will not be compensated for.

The precautionary principle would argue for an aggressive mitigation policy. This is even more the case if the possibility of catastrophic events is taken into account. Even if the probability of these catastrophic events is not known, as much as possible may be done to avoid a worst-case scenario. If the density of probability is known, the relevance of catastrophic events depend on how quickly their probability diminishes as their intensity increases. If this density has a "fat tail", catastrophic events have an infinitely negative expected utility that overwhelm cost-benefit analysis.[8,9] Depending on preferences, this could justify putting all our resources into fighting climate change to avoid catastrophic risks. Many issues, however, feature tails that may be fat. For example: the risk of a nuclear war. Moreover, an aggressive mitigation policy that would disrupt the economic system may generate its own fat tail. Is there something special about climate change that makes the presence of uncertainty lead to a greater need for action than for other issues?

- The risk is global, and climate change may be irreversible, given current technologies. While learning as the process unfolds and making midcourse corrections is possible, it is made difficult by delayed impacts.
- The process has already started.

While these characteristics make uncertainties in climate change especially dangerous, it does not make it unique. This said, it seems that for climate change issues uncertainty pleads for an aggressive mitigation policy. Uncertainty should thus not be construed as a rationale for mitigating less. On the contrary: the uncertainty related to the global impact on the planet can be a reason to mitigate more. Less aggressive measures increases the expected climate change and the risk of global catastrophic events.

Adaptation

The issue is more differentiated for adaptation policies. The wait-and-see approach might be appropriate for some adaptation policies. For example, if construction time is not too long, it may make sense to wait for more precise information before building a dyke against floods. Early adaptation may, however, be appropriate for some long-lived infrastructure that will be built anyway. For developing countries, a key issue is how to exploit synergies between development and climate-change adaptation. Adaptation suffers from the uncertainty about the magnitude of climate change, but does not depend on whether other countries also launch adaptation policies.

A significant level of deep uncertainty is likely to remain for a long time. Robustness and flexibility are key to deal with deep uncertainty. Robust policies are policies that might not be optimal in any state of the world, but are good in a broad set of states. Flexibility is the ability to adapt quickly to incoming information or new events. All other things remaining equal, low public debt and good public education, for example, enhance flexibility.

What does this uncertainty imply for including climate change in fiscal sustainability reports?

Uncertainty is a key challenge to introducing climate change into fiscal reports. This section discusses how to deal with it, for example by using sensitivity analysis.

Increased public expenditures and lower tax revenues would lead to increased public deficits and debt. If the magnitude is not too high, this can be compensated for by a reduction of other public expenditures and a tax increase. It is thus important to quantify the order of magnitude of fiscal effects. Moreover, it is important to assess the degree of persistence of these effects. In so far as these effects are transitory, an increase of public debt (if public debt is not too high to begin with) will spread the financial effort over time. It may even be appropriate to reduce public debt in anticipation. In so far as they are permanent, these effects will not justify an increase of the public debt. Therefore information about the magnitude and the persistence of the fiscal impact is needed.

Knowing a maximum bound for the fiscal impact is in some cases sufficient for assessing fiscal sustainability. An increase of public expenditures of less than 10% in 2100 would for example seem quite manageable for a country starting with healthy public finances since, even with a moderate growth rate of the economy, the country will be much richer 80 years from now.[10] Fiscal sustainability would however look very different if the cost of climate change is much higher. The average tax rates cannot exceed 100% and already reduce incentives for economic activity far before reaching this bound. There are also limits to how much room public expenditures not related to climate change can leave for increased expenditures related to climate change. Some public expenditures not related to climate change may have to increase like GDP, for example those transfers aiming at limiting inequalities (although it is debatable how much increase in intergenerational inequality should be accepted in order to preserve intergenerational equality). Other expenditures tend to increase even faster (health care). The fiscal issue will be the most acute if GDP growth slows sharply. This may be the case in catastrophic climate scenarios or if the only way to reduce GHG emissions sufficiently implies reducing economic activity (because the reduction of carbon intensity of GDP is insufficient). More precise information is needed if the parameters are such that a small change would make the difference between sustainable and unsustainable public finances. In any case, sensitivity analysis is a good way to understand the implications of uncertainty, when that uncertainty is not too deep. The fat-tail issue should be taken into account in comparison with other fat-tail issues rather than in isolation. Very deep uncertainty cannot be taken into account quantitatively. It may however plead for flexible policies and improving the robustness of the country.

Not only the amplitude, but also the timing of the fiscal impact is important, in particular whether it coincides or not with the maximal fiscal pressure arising from population ageing.

There are several ways to provide a quantitative analysis. One way is to begin with the whole image, however blurred, and then try to make it sharper. A more common way is to begin with pieces that can more readily be quantified and then try to add new pieces of this puzzle. Still another approach is to begin with short-term impacts and then try to increase the time horizon. Whatever the approach, it is often more like learning a language (each new word is useful) than like making a clock (the clock is useful only when completed). It may be relevant to list the policy questions that have to be answered (besides fiscal sustainability) and look at what information would help to answer which question. Even basic information may be sufficient for example to conclude that tax revenues on motor-oil will diminish as the share of electric vehicles increases, or that a tax on CO_2 should be introduced as soon as possible in order to be increased as smoothly as possible. Including a qualitative discussion of the fiscal impact of climate change in a sustainability report at least demonstrates awareness of the issue. There is, however, an important sense in which computing the fiscal impact is more like building a clock: as long as the impact through a potentially major channel is unknown (or known with a very high degree of uncertainty), it is not possible to tell what the overall impact will be. But if the sign of the missing element is known, this at least allows to compute a lower or an upper bound of the fiscal impact.

Available studies about the long-term fiscal impact of climate change

The goal of this chapter is to provide information for countries that are considering taking account of the long-term fiscal impact of climate change in their fiscal sustainability report or other official fiscal reports. In this literature review, the focus lies on the sparse literature on the long-term fiscal impact of climate change that could be helpful in this regard, with special attention to the methodology that could inspire other countries. Some results will also be shown for illustration. Although it is a prerequisite for studying the fiscal impact, this chapter does not present the large literature on economic impacts (when it does not refer to the fiscal impact).[11] This chapter does also not review the large literature about fiscal instruments for GHG emissions mitigation, in particular CO_2 taxes.[12] Finally, it does not discuss the nascent literature on the short-term fiscal impact of climate change that is addressed by other areas of green budgeting.

Fiscal sustainability reports mostly focus on demographic developments and their impact on expenditure on health, long-term care, social security, education and other demography-related positions. Some studies extend their analysis to other long-term challenges for public finances such as immigration. Until now, the effects of climate change and other environmental risks are usually not taken into account. An exception is the Swiss fiscal sustainability report which briefly discusses climate change, in, however, a qualitative and brief manner. The best-known sustainability reports include the “Fiscal Sustainability Report” and the “Ageing Report” of the European Commission (European Commission, 2018a and 2019), the “Long-Term Budget Outlook” of the US Congress (CBO, 2019), the “Fiscal Sustainability Report” of the UK Treasury (OBR, 2018) and the “Bericht zur Tragfähigkeit der öffentlichen Finanzen” of Germany’s Federal Ministry of Finance (BMF, 2016). All these reports are published regularly.

The Swiss fiscal sustainability report is mentioned in §4.1 and presented in more detail in Annex A. While fiscal sustainability reports typically do not discuss the fiscal impact of climate change, some rare other official reports do. These include OBR (2019) for UK, European Commission (2020) for the European Union and OMB (2016) for US. These reports are presented in §4.1 and §4.2. Quantitative studies about the fiscal impact of climate-change adaptation are presented in §4.3. The most comprehensive quantitative studies of the fiscal impact of climate change are not official reports. They are presented in §4.4.

Box 1. Fiscal sustainability versus fiscal risks

Fiscal sustainability is the ability of a government to sustain its current spending, tax and other policies in the long run without threatening government solvency or defaulting on any of its liabilities or promised expenditures. Fiscal risks are defined as the possibility of deviations of fiscal outcomes from what was expected at the time of the budget or other forecast. Fiscal risks are not included in fiscal sustainability forecasts because they are considered uncertain or unlikely.

As long as its magnitude is too uncertain, climate change is merely a risk and it is appropriate not to include it in the main parameters of a fiscal sustainability report. A fiscal sustainability report can, however, contain a section describing qualitatively the risks not taken into account in the quantitative assessment. With increasing certainty of climate change impacts, in so far as the fiscal impact of climate change is quantifiable, it can be quantitatively included in the fiscal sustainability report. In a first step, one option is to include a lower bound that takes into account only the channels that are the easiest to quantify.

4.1. Qualitative discussion of the fiscal impact of climate change in official reports

Switzerland

In Switzerland, a first qualitative presentation of possible impacts of climate change on public budgets was presented in the long-term fiscal sustainability report in 2016 (FDF 2016). Annex A provides a more detailed description of this assessment. The 2020 report will contain a somewhat longer section about climate change, but will remain qualitative.

United Kingdom

While the UK Fiscal Sustainability Report does not discuss climate change, the Fiscal Risks Report produced by the Office for Budget Responsibility (OBR) has started to take climate change risk into account. The Fiscal Risks Report is an assessment of shocks and pressures that could threaten the forecast for public finances over the medium term and fiscal sustainability over the longer term. The last issue (OBR, 2019) contains a detailed qualitative discussion of the long-term fiscal impact of climate change in an official fiscal report. After citing evidences of climate change (globally and in the UK), it mentions the participation of the UK in the Paris Agreement and the target of the UK government of reaching net zero greenhouse gas emissions by 2050. It then refers to other reports. It indicates that in the previous Fiscal Risk Report published in 2017, climate change was mentioned as a potentially significant source of fiscal risk that was not analysed. OBR (2019) also refers to the most recent UK Government's Climate Change Risk Assessment that assesses the risks and opportunities arising from climate change and identifies six priority risks. These risks are, however, mostly not quantified. OBR (2019) mentions the Network for Greening the Financial System (NGFS) and the way that its scenario analysis framework takes into account the strength of the greenhouse gas mitigating policy and how smoothly and foreseeably those actions are taken. OBR (2019) builds on the work of the Bank of England (Bank of England, 2015 and Batten, 2018) that provides a framework for climate-related financial stability risks. This framework is also relevant for analysing fiscal sustainability risks since, like financial stability risks, they are affected by risks to the economy (the key difference being that tax and spending policies can affect the path of climate change whereas climate change is exogenous to financial stability). This framework distinguishes two channels: i) *physical risks* that arise from climate- and weather-related events and ii) *transition risks* resulting from the process of adjustment towards a lower-carbon economy. These risks are broken down into those affecting the supply side and demand side of the economy in the following table.

Table 1. Examples of macroeconomic risks from climate change

Type of shock/impact		Physical risks: From extreme weather events	Physical risks: From gradual global warming	Transition risks
Demand	Investment	Uncertainty about climate events		'*Crowding out*' from climate policies
	Consumption	Increased risk of flooding to residential property		'*Crowding out*' from climate policies
	Trade	Disruption to import/export flows		Distortions from asymmetric climate policies
Supply	Labour supply	Loss of hours worked due to natural disasters	Loss of hours worked due to extreme heat	
	Energy, food and other inputs	Food and other input shortages		Risks to energy supply
	Capital stock	Damage due to extreme weather	Diversion of resources from productive investment to adaptation capital	Diversion of resources from productive investment to mitigation activities
	Technology	Diversion of resources from innovation to reconstruction and replacement	Diversion of resources from innovation to adaptation capital	Uncertainty about the rate of innovation and adoption of clean energy technologies

Source: Batten (2018) as reproduced in OBR (2019)

OBR (2019) then discusses the nature of climate-related fiscal risks and their relative scale. It distinguishes three types of fiscal risks:

- *Fiscal risk from extreme weather events*
  Fiscal risks from extreme weather events include costs of infrastructure damage and depreciation. To the extent that extreme weather events reduce economic activity (rather than merely shifting it over time), tax revenues would be hit and the social security bill would rise. Were the Government to choose to meet some of the costs of repairing and rebuilding private property – or to spend more to restore assets of its own that were damaged – public spending could be higher. The scale of such risks would depend on the precise nature of the extreme weather event. The fiscal implications of past extreme events were modest. A coastal surge that led to severe flooding in the Thames estuary could have more significant fiscal consequences.
- *Fiscal risks from adaptation to climate change (gradual global warming)*
  Fiscal risks from adaptation to climate change depend on the extent to which temperature rises. After summarising the literature on adaptation costs at the international level, the report notes that "As well as the fiscal implications of any effects of climate change on GDP and the tax base [diverting investment to adaptation needs could impinge on investment in productive capital], adaptation can generate more direct fiscal costs. For example, the Environment Agency has estimated that an average of £1 billion a year will need to be spent on flooding and coastal infrastructure in order to be resilient to a 4°C rise in global temperatures. […] Of course, in a 4°C world, the public spending implications of conflict and mass migration could represent a far more significant source of fiscal risk than those of flood defences and coastal protection."
- *Fiscal risks from the transition to a low-carbon economy (related to mitigation policies)*
  As far as fiscal risks from the transition to a low-carbon economy are concerned, such policies are typically considered to be an economic burden in the shorter run (increasing taxes, diverting resources to climate change mitigation from other productive activities and raising input costs). In the long run,

however, successful mitigation would reduce the economic costs of gradual global warming. The macroeconomic risks of climate policy will depend on how it is managed: well-signalled and orderly policies that allow time for the economy to adjust and for technological advances to reduce costs might pose little risk. The report cites a value of £1 trillion for the total cost – both public and private – of meeting the emission target of the government (compared to a real GDP of £90 trillion and total public spending of £40 trillion). Successful mitigation of greenhouse gas emissions can create its own fiscal risks, to the extent that tax revenues (fuel duty revenue for example) are currently dependent on emission-generating activities. If the financial system were to suffer from the consequences of stranded assets and under-priced risks, tax revenues from one of the most tax-rich sectors of the economy could be hit.

OBR (2019) sees the following risks for fiscal sustainability. Redirecting resources to adaptation and mitigation activities may weigh on productivity growth. However, there may also be opportunities to boost the economy by reorienting it towards green technologies. There are risks from the direct pressures placed on tax revenues and public spending such as the declining fuel duty tax base or requirement for extra spending on flood defences. Overall, the OBR considers the fiscal implications of climate change to be small relative to those of population ageing or the cost pressures seen in health care. However, this conclusion might simply reflect the difficulty in seeing through to the full systemic consequences of significant global warming.

Finally, OBR (2019) sets out next steps that it plans to take. Two collaborative workstreams have been launched: i) with the Bank of England and ii) between the OECD network of fiscal councils and the NGFS.

European Union

The Commission's proposal in December 2019 for a European Green Deal includes an increase of the EU's climate ambition in terms of reduction in GHG emissions by 2030 from 40% to 50/55%, with the aim of achieving climate-neutrality by 2050 in continental Europe.

The European Commission did not mention climate change in its last Fiscal Sustainability Report (2018), but discusses it in a report that provides an overview of fiscal sustainability challenges faced by EU Member States over the short, medium and long term: the Debt Sustainability Monitor 2019 published in January 2020 (European Commission, 2020). This is motivated by the potentially high macroeconomic and fiscal costs linked to climate change. Given the complexity of the exercise, and important data gaps, European Commission (2020) provides only a first contribution, focusing on conceptual and practical considerations, based on the existing rich literature. It discusses how the climate change dimension could be considered in the Commission debt sustainability analysis (DSA) framework, while stressing the many conceptual and practical challenges involved (e.g. numerous transmission channels, limitations of existing economic modelling tools, data gaps). Climate change risks could be integrated into the Commission debt sustainability analysis framework via stress test analysis, alternative policy scenarios and the consideration of additional mitigating / aggravating risk factors:

- *Extreme weather events*
  The impact of extreme weather events could be evaluated by including in the DSA a customized stress test scenario, where the impact on growth and public finances, including on debt and the capacity to pay, would be calibrated to country-specific characteristics.
- *Gradual transformation*
  The impact of the gradual transformation of the environment (for different paths of GHG emissions) could be included in the DSA in the baseline macro-fiscal projections along with the legislated policy measures, while the policy commitments could be considered in alternative policy scenarios, in which the implications of climate risks and policies would be incorporated into alternative macro-fiscal projections.

- *Other aggravating / mitigating factors*
  Other aggravating / mitigating factors to consider in stress tests and policy scenarios: i) the potential impact of contingent liabilities linked explicitly to government guarantees or, implicitly, to the (lack of) resilience of the financial sector to climate change risks, ii) The risk sharing of climate-related events between private and public sector through specific climate-related financial instruments, iii) Other macroeconomic policies, such as regulatory measures, financial and monetary policy tools. The DSA baseline, stress tests and policy scenario analysis can include different assumptions on the path for GHGs emissions, yet, assuming policy action will contain the risk of catastrophic irreversible climate change (tipping points).

Data availability appears as a key challenge for future developments of fiscal risk analysis linked to climate change. Current modelling tools, for example cost-benefit models (Integrated Assessment Models), present important limitations. Current budgetary frameworks often present limitations for the purpose of assessing fiscal risks associated with climate change. For example, the current reporting under the Stability and Convergence Programs does not include a commonly agreed framework and a "green" taxonomy for estimates of climate-related fiscal costs.

The next table presents possible impacts on public finances related to climate change (it does not necessarily cover all possible impacts).

Table 2. Fiscal impacts: non-discretionary vs. discretionary measures

Non-discretionary (exogenously driven, by climate change phenomenon)	Discretionary impact (endogenously driven, through policy measures)
Direct (examples): • Public spending to replace damaged infrastructure/buildings • Social transfers to households affected by the weather event • Materialization of *explicit* contingent liabilities (e.g. insurance schemes backed by state guarantees)	*Adaptation policies (examples):* • Public investment in climate-proofing infrastructure, water management • Subsidies to support changing crop varieties, or relocation from coastal areas • "Rainy day" funds
Indirect (examples): • Reduction of tax revenue due to a reduction in economic activity • Increase of health care spending due to more diseases • Materialization of *implicit* contingent liabilities (e.g. to support financial institutions in distress) • Impact on the sovereign capacity to pay debt payment obligations over the medium-term (due to budgetary funds reallocation towards recovery/reconstruction)	*Mitigation policies (examples):* • Carbon taxes (e.g. on fossil fuels, and other carbon taxes). Adverse impact on economic activity in the short term, with uncertain net impact on the overall tax revenues in the medium and long-term • Emission trading schemes (ETS) revenues • Public subsidies for clean energy transition • Redistribution effects on the tax base

Source: European Commission (2020)

For future work, the European Commission considers that a step-by-step approach appears warranted, starting by performing case studies in EU countries for which exposure to climate change is particularly severe, and / or where information is available. First results could be presented in the next update of the Debt Sustainability Monitor.

4.2. Quantitative discussion of the fiscal impact of climate change in official reports

Few OECD countries have attempted to quantify the fiscal impact of climate change. While the US Office of Management and Budget (OMB) has produced an official report in 2016, other countries addressed the topic in external studies (see section 4.3).

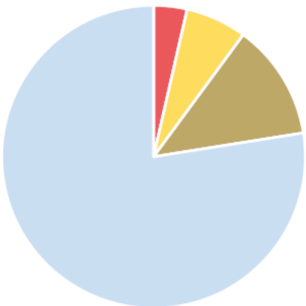
United States

The "Long-Term Budget Outlook" of the US Congress does not discuss climate change. However, the fiscal impact of climate change is discussed in OMB (2016) by the Office of Management and Budget. This report is entitled "Climate Change: The Fiscal Risks Facing the Federal Government – A Preliminary Assessment". This section focuses on the quantitative contribution of the report.

OMB (2016) outlines fiscal risks in five program-specific assessments for which the scientific and economic literature has produced quantitative modelling of impacts. The figure below provides estimates for the increase in expenditures in four of these fields: coastal disaster relief, air quality health care, crop insurance, wildland fire suppression. In addition to these four program areas, OMB identified significant flood risks to federal property after reviewing a sample of the federal inventory but has not estimated the likely costs associated with these liabilities over the coming decades.

Figure 6. Quantified increases in annual expenditures

Quantified Increases in Annual Expenditures Due to Climate Change in Modeled Scenarios [a]



Late-century mean

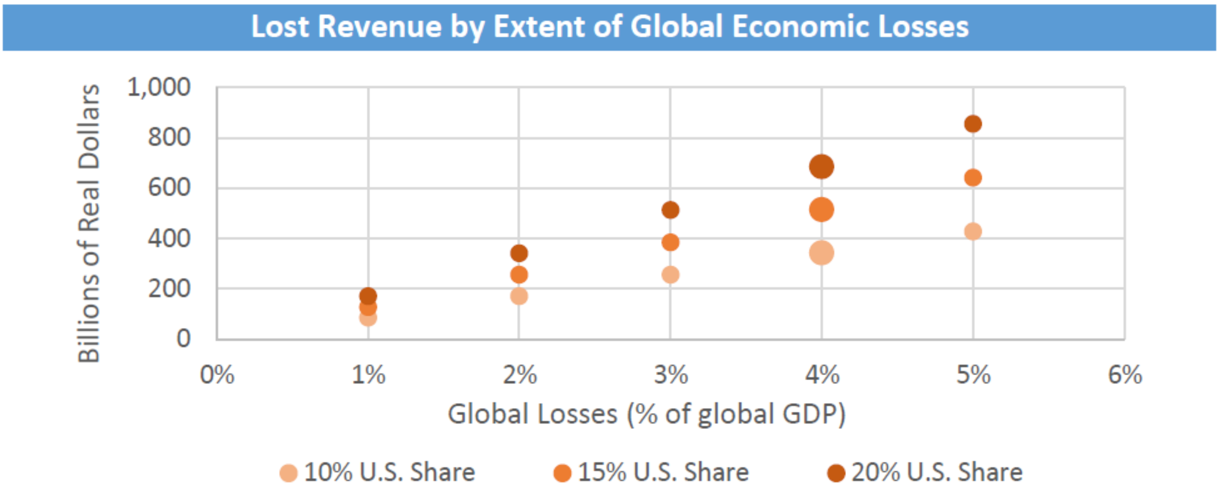
Billions of Real dollars (GDP-Adjusted) [b]	Mid-Century Mean	Mid-Century Lo [c]	Mid-Century Hi [c]	Late-Century Mean	Late-Century Lo [c]	Late-Century Hi [c]
Wildland Fire Suppression	**$1.3** ***($0.6)***	$0.8 *($0.4)*	$2.0 *($0.9)*	**$2.3** ***($0.5)***	$1.2 *($0.2)*	$5.0 *($1.0)*
Crop Insurance [d]	--	--	--	**$4.2** ***($1.0)***	<$0.1 *(<$0.1)*	$9.3 *($2.3)*
Air Quality-Health Care [e]	**$0.6** ***($0.3)***	<0.1 *(<$0.1)*	$1.5 *($0.7)*	**$7.7** ***($1.2)***	$0.6 *($0.1)*	$19.7 *($3.2)*
Coastal Disaster Relief	**$19** ***($8.7)***	$11 *($5.0)*	$31 *($14.2)*	**$50** ***($13.6)***	$32 *($8.7)*	$78 *($21.2)*
Total Annual Expenditures [f]	**$21** ***($9.6)***	$12 *($5.4)*	$35 *($15.8)*	**$64** ***($16.3)***	$34 *($9.0)*	$112 *($27.6)*

[a] The costs in this table are not predictions of the future; they are projections of costs that would be incurred by the Federal Government given a set of assumptions that form the scenarios modeled. See each assessment for more information.
[b] Estimates represent snapshots of average annual expenditures due to climate change in the year(s) modeled for this assessment. Topline estimates are in billions of real dollars. Below the topline estimates *(in parentheses)* are equivalent dollar estimates in today's economy in terms of percent of U.S. GDP. Adjustment factors vary due to differences in years modeled.
[c] The range between Lo and Hi estimates reflects only a portion of the uncertainty associated with cost estimates. See relevant sections of this report for more information.
[d] Crop insurance expenditures were only modeled for the late-century time period (2080).
[e] While the other three assessments compare an unmitigated climate change scenario to a scenario characterized by historical weather patterns, the air quality assessment compares an unmitigated climate change scenario to a *mitigation policy scenario*. As discussed in the assessment, mid-century estimates may capture less than half of the full cost increase due to unmitigated climate change, while late-century estimates likely capture the vast majority of the increase.
[f] Several likely areas of fiscal risk related to climate change have not yet been quantified.

Source: OMB (2016)

The report also considers potential impacts to federal revenues. For illustrative purposes, the figure below shows outcomes for lost federal revenue in late-century under various assumptions about global (world) economic losses (as a share of global GDP) and the US share of these global losses. At four degrees Celsius warming, OMB (2016) mentions a global economic loss of four percent of global GDP as a commonly cited estimate. The US share of climate change damages in mid- and late-century (expressed in terms of GDP) is likely to be lower than the current US share of global GDP for two reasons. First, with its high income and well-developed institutions, the US can expect to suffer proportionally less than the average country so that its share of global loss should be less than its share of global GDP. Second, the US share of global GDP (around 22% of nominal global GDP in 2015), is likely to decline gradually over time as emerging countries become richer. Federal revenue is held constant as a share of US GDP and all economic losses are assumed to translate into lost GDP (i.e. no non-market losses that do not translate into lost GDP).

Figure 7. Lost fiscal revenue



U.S. Share	Global Losses: 1%	2%	3%	**4%**	5%
10%	$86 *($14)*	$171 *($28)*	$257 *($42)*	**$343 *($56)***	$428 *($69)*
15%	$128 *($21)*	$257 *($42)*	$385 *($62)*	**$514 *($83)***	$642 *($104)*
20%	$171 *($28)*	$343 *($56)*	$514 *($83)*	**$685 *($111)***	$856 *($139)*

Estimates are in billions of real dollars and *(in parentheses)* the equivalent dollar estimates in today's economy in terms of percent of U.S. GDP.

Source: OMB (2016)

While OMB (2016) presents a quantitative discussion, it is not comprehensive. However, OMB (2016) is very explicit about the limitations of its study as these few passages show: "although the combined weight of the quantified mean expenditure estimates in the assessments in this report reaches into the tens of billions to hundreds of billions per year by late-century, this is only a narrow window into the full fiscal risks of climate change. Fiscal impacts in several areas exposed to potentially significant climate risk are not quantified in this report due to data limitations and other challenges. Among these are health care related to vector-borne diseases and other climate change health impacts, national security, the National Flood Insurance Program (NFIP), transportation and water infrastructure, and inland Federal asset flood risk. […] the assessments do not attempt to fully represent the potential for adaptation or policy changes to attenuate fiscal impacts […] the estimates do not account for important factors that remain difficult to quantify in physical terms and are inherently difficult to monetize, such as biodiversity loss, ocean acidification, changes in weather related to changes in ocean circulation, increased severity of certain extreme events, tipping points associated with non-linear changes in the climate, and heightened political instability as a result of climate impacts. In addition, current models factor in economic damages over time but treat the rate of economic growth as if it is unaffected by climate change. […] The uncertainty of economic damage projections is compounded when attempting to estimate the associated potential for lost U.S. Federal revenue. The exercise relies on difficult assumptions about the U.S. share of global economic losses, the impact of economic losses on U.S. GDP, and Federal revenue as a share of U.S. GDP. For example, while economic losses are commonly expressed as a percent of global output, some portion of those losses occur in the form of non-market losses (e.g., premature mortality or biodiversity loss) that may not directly translate into lost GDP—or Federal revenue […] the actual fiscal risks to the Federal Government are likely to be much greater than the sum of what is quantified in this preliminary assessment".

Finally, OMB (2016) charts a path to a clearer picture of fiscal risks. It plans collaborations to build future fiscal and economic risk assessments on an ever-growing body of relevant and reliable scientific information.

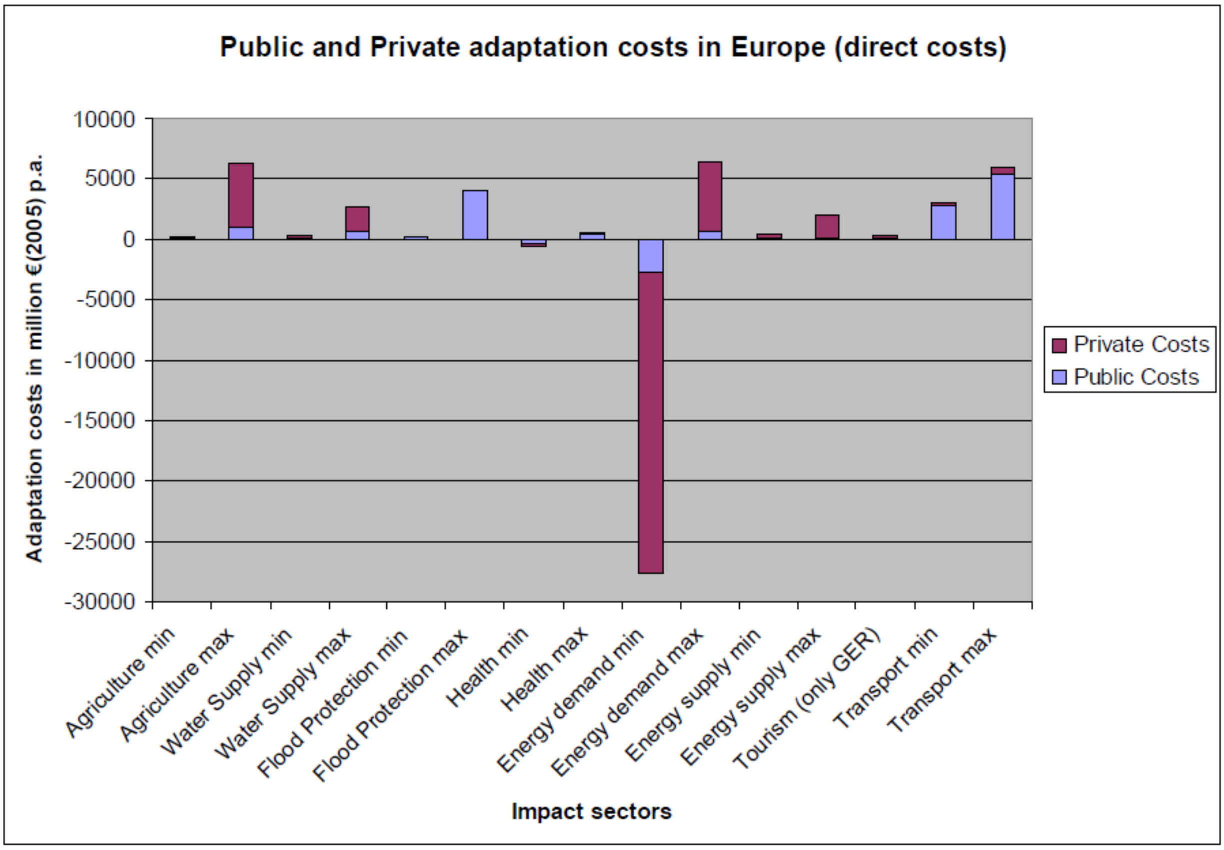
4.3. Quantitative studies of the fiscal impact of climate-change adaptation

When considering the fiscal impact of climate change, adaptation often comes first to mind. The review is limited mainly to two papers: CEPS and ZEW (2010) and World Bank (2010).[1]

CEPS and ZEW (2010) study the fiscal implications of climate-change adaptation in the European Union, but they also provide a framework that could be useful more generally. They offer in particular an interesting discussion of why the state typically contributes to adaptation: i) some market failures (imperfect information, moral hazard, …) may make autonomous adaptation by individual agents suboptimal, ii) equity issues, iii) security of supply of public goods or essential goods and services. One of the cornerstones of this paper is the analysis of insurance markets. It explores for example public–private partnerships, such as state guarantees for excessive uninsurable damages. The paper also summarizes case study results for the fiscal implications for Germany, Italy and Finland. The results of the case studies, complemented by top-down cost estimates of adaptation measures in Europe, are presented in an adaptation cost matrix. The purpose is two-fold: i) the knowledge gaps become visible at a glance, ii) the matrix provides a systematic review and classification of various literature sources. The cost estimates in the matrix show relatively high adaptation costs for agriculture, coastal protection and transport infrastructure (and possibly high negative costs in energy demand). See also Osberghaus and Reif (2010) for cost estimates for adaptation in Europe, and in particular Germany, Finland and Italy. The following figure presents private and public adaptation costs in Europe. However, the comparability of the bars is limited, as the values are derived from different studies (including different methodologies, models, assumptions, time horizons and climate scenarios). The lowest and the highest cost value for each sector are included, so that the large range of possible outcomes is illustrated. These cost estimates are very uncertain, but this figure illustrates the kind of information that should be gathered. Concerning energy demand, Osberghaus and Reif (2010) write: "Adaptation of demand is likely to result in more demand for cooling and less demand for heating energy. Although this behaviour seems trivial and could be interpreted as a form of impact, it fulfils the criteria of a reactive adaptation measure, as defined by the IPCC. […] Budgetary effects of this adaptation behaviour may arise to the extent buildings are owned and maintained (heated and cooled) by governmental entities."

[1] There are several other papers on the subject. Some of them are cited in Bachner and Bednar-Friedl (2019), the paper about Austria that we discuss in §4.4. These authors are also coauthors of Bachner et al. (2019) more specifically focused on adaptation and which also mentions other studies. Some international institutions (IMF, World Bank) and some countries have introduced fiscal stress tests for natural disasters related or unrelated to climate change.

Figure 8. Private and public adaptation costs in Europe



Source: CEPS and ZEW (2010) page 80 and Osberghaus and Reif (2010)

World Bank (2010) studies the cost to developing countries of adapting to climate change. It finds that the cost between 2010 and 2050 of adapting to an approximately 2°C warmer world by 2050 is in the range of $75 billion to $100 billion a year. This range is of the same order of magnitude as the foreign aid that developed countries now give developing countries each year, but it is still a very low percentage of the wealth of countries as measured by their GDP.

4.4. Quantitative studies of impact on spending and revenues

The most comprehensive quantitative studies of the fiscal impact of climate change have not been produced by governments. The first study we are aware of that quantifies the impact on public expenditures and fiscal revenues through a broad range of sectors is Infras/Ecologic (2009) done for the German Federal Ministry of Finance. Bachner and Bednar-Friedl (2019) did a study on Austria.

Germany

Infras/Ecologic (2009) was the first study systematically and comprehensively analysing the impact of climate change on the sustainability of public finances. The study combines qualitative and quantitative approaches to estimate the impact on public finance both on the expenditure and revenue sides. The study builds on the global IPCC scenarios, representing a lower and an upper bound on future greenhouse gas emissions. A socio-economic baseline scenario for Germany is developed based on the projections by the German Ministry of Finance regarding demographic change and future economic growth. Expected economic damages as well as positive effects of climate change are then expressed as a deviation from the baseline scenario (no climate change).

The quantitative impact is computed for 2050 and 2100. Uncertainty is taken into account through a Monte-Carlo simulation. Socio-economic impacts are assessed through ten case studies. Eight of these investigate the sectors likely to be most affected: damage to buildings, agriculture and forestry, energy supply, water supply, tourism, transport, insurance and the health sector. Two cross-sectional case studies look at the impacts of rising sea levels and the effects transmitted through international trade. An important issue is how to take account of adaptation. This study takes the cost estimates for the expansion of existing protection and adaptation measures into account and includes them in the quantification. In contrast, new and previously untested instruments are only considered in the qualitative analysis.

The study finds that climate change has a significant impact on public finances: In 2100, falling revenues and increased spending could result in a negative impact on the public budget equivalent to a GDP loss of 0.6% to 2.5% compared to the reference scenario. This corresponds to 1.3% to 5.7% of the state budget (strangely, expressed as percent of the 2050 budget). In 2050, results are more ambivalent: depending on the assumptions for different impact categories, climate change could either have a slightly positive effect on public spending – equivalent to a GDP gain of 0.05% - or result in a loss of up to 0.31% of GDP. Overall, the effects transmitted through international trade (falling demand for exports) are the most sizeable negative impact, whereas tourism is expected to benefit significantly (see figure below). While considering this numbers, it should be remembered that not all impacts could be quantified. Climate change could eventually become a burden for public finances equal to demographic change (the authors compute an estimate of the climate change burden that is smaller than the one of demographic change, but consider that the two are of comparable magnitude given uncertainties). However, the peaks of those two burdens will hit public finances at different times. In 2050, when public finances are heavily burdened by additional spending for the ageing population, climate change will only have its first noticeable impacts. Towards the end of the century, the fiscal effects of climate change are expected to increase significantly.

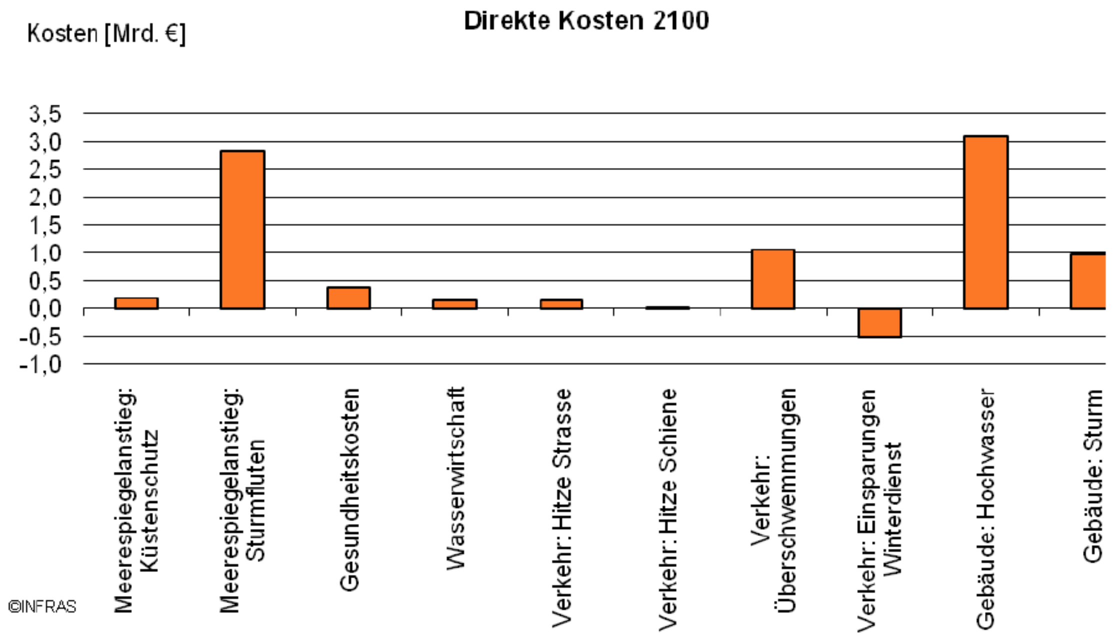
Assessment

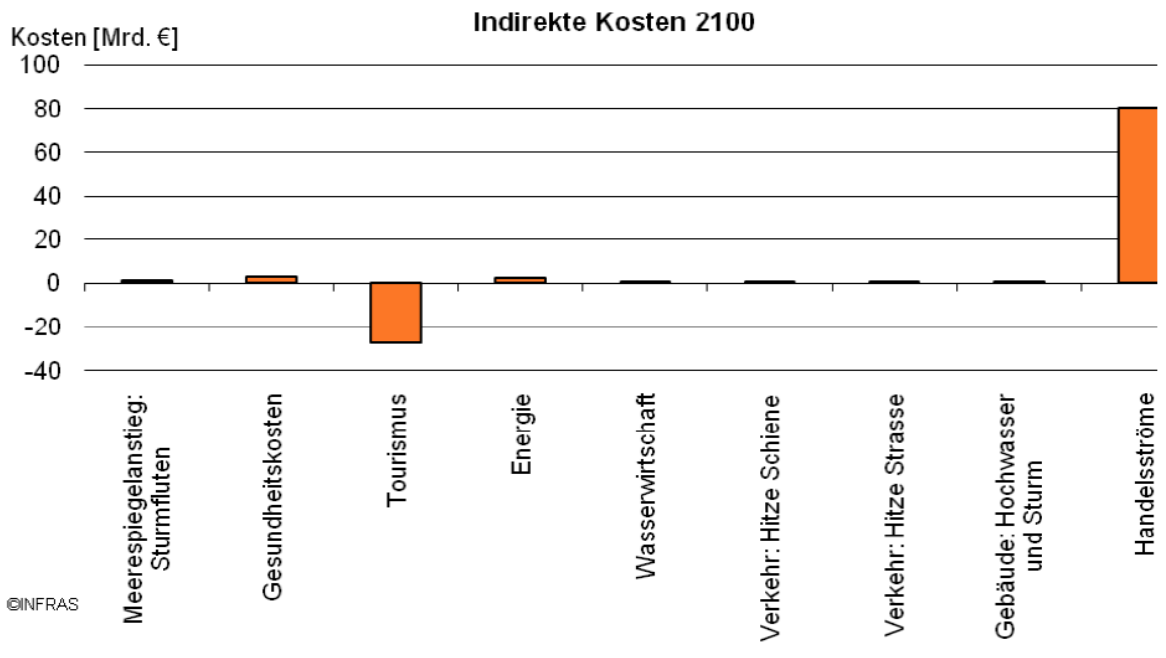
As the above figure shows, the dominance of the international trade channel is overwhelming: a 80 billion euro reduction of fiscal revenues because of reduced demand for German exports (“Handelsströme”), whereas the next most important sector is tourism, far behind with additional tax revenues of less than 30 billion euros, and the highest impact of public expenditure is much smaller at about 3 billion euros for flood damage to buildings. This means that the results are especially sensitive to assumptions about the impact of climate change on the demand for German exports. These assumptions concern how much Germany would export to which country in 2100 in the absence of climate change, how much climate change will affect each of these countries and how this will translate into reduced demand for German exports (this will depend on the type of exports: there may for example be increased demand for adaptation technology and reduced demand for luxury goods).

All these assumptions are highly uncertain. It would be particularly difficult to predict how exporters will adapt in changing export markets and products. Moreover, the study counts the reduction in exports as a reduction in GDP (after taking into account the implied reduction in imported inputs). It is however unlikely that the corresponding production factor will remain unused. Indeed, the authors describe this part of GDP as “at risk” and say explicitly that it will not necessarily disappear.[2]

[2] “The quantification does not show the amount of exports and ultimately the added value that will disappear due to the climate in Germany. It shows the proportion of exports or GDP that is at risk” (page 105).

Figure 9. Average impact through various channels





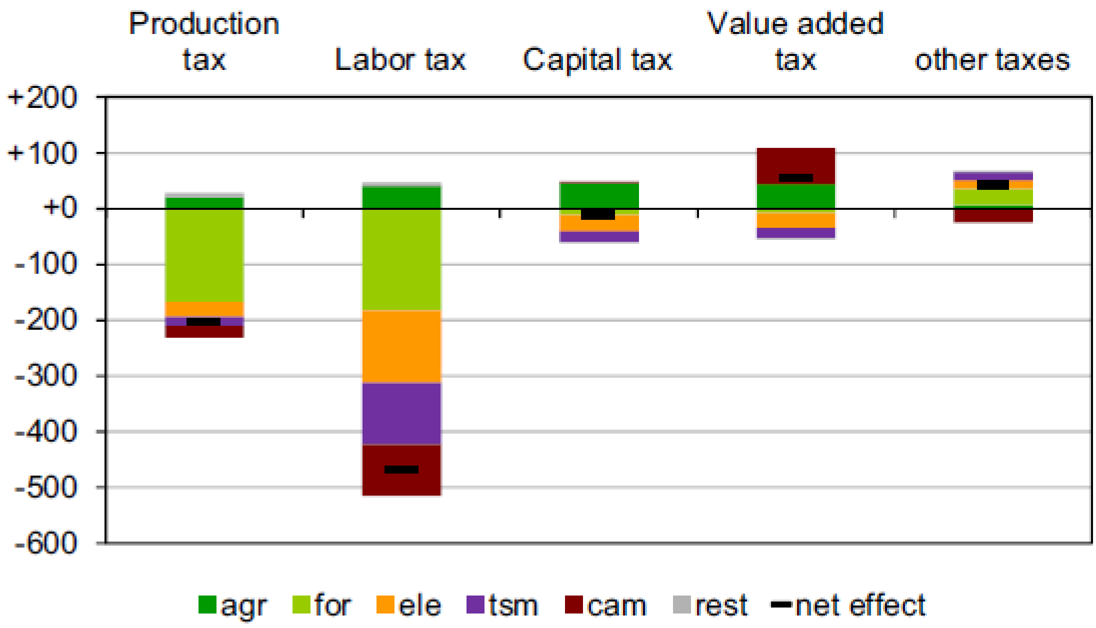
Source: Infras and Ecologic (2009)

Austria

For Austria, Bachner and Bednar-Friedl (2019, published online in 2018) use a computable general equilibrium model to calculate the impact of climate change in ten climate-sensitive sectors as well as public expenditures for disaster relief and reconstruction of public infrastructure. All scenarios describe different developments from the model base year (2008) to 2050. The end point 2050 is chosen because projections on socioeconomic development (population, land use etc.) and long-term government budget planning are available. Climate mitigation policy is held constant. To ensure fiscal stability, debt-to-GDP ratio is assumed to be constant. Climate change impacts are identified and implemented across ten climate change impact fields: agriculture, forestry, water supply and sanitation, buildings, electricity, transport, manufacturing and trade, cities and urban green, catastrophe management, and tourism.

The negative impact on revenues is mostly due to the negative impact on forestry (lower production, pest infestations), but impacts in electricity production (reduction of hydropower production), tourism (reduced winter tourism demand) and catastrophe management (higher expenditures on disaster compensation) also substantially reduce tax income. Production and labour tax are particularly impacted.

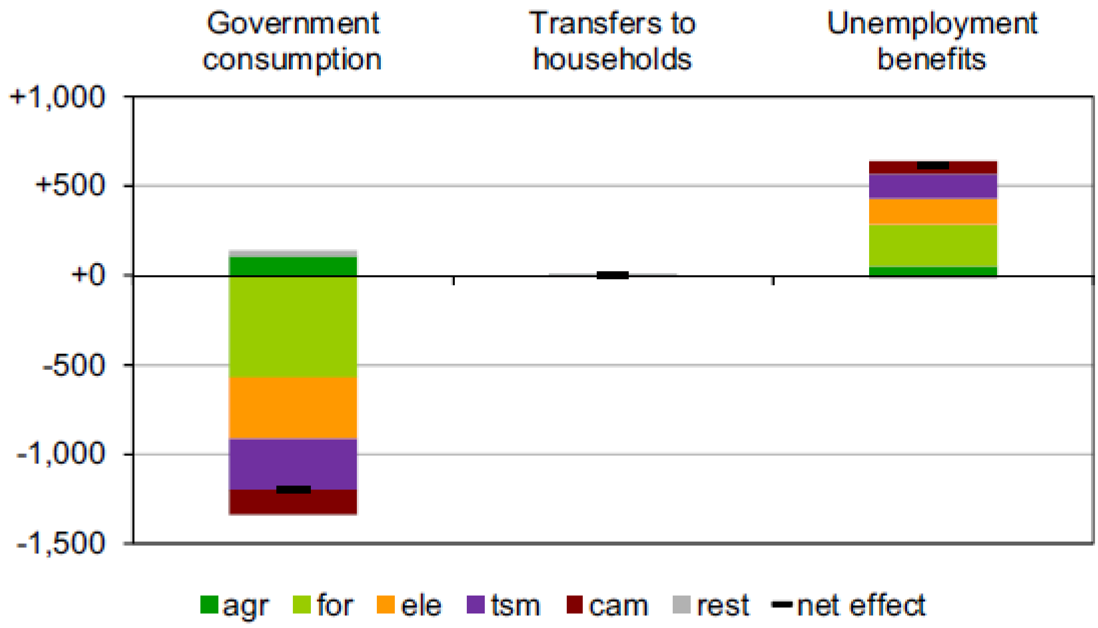
Figure 10. Changes in fiscal revenues in 2050 in the No-Counterbalancing scenario, by impact chain relative to Baseline scenario (= without climate change) in million euros 2008 (for comparison: GDP 2050 = 555 billion euros 2008)



Note: Impact fileds: Agriculture (agr), Forestry (for), Electricity (ele), Tourism (tsm), Catastrophe Management (cam), and rest: Heating and Cooling, Water, Transport, Manufacturing and Trade, Cities and Urban Green.
Source: Bachner and Bednar-Friedl (2019)

On the expenditure side, negative effects are again dominated by forestry. It is mainly expenditures for unemployment benefits that increase.

Figure 11. Changes in public expenditures in 2050 in the No-Counterbalancing scenario, by impact chain relative to Baseline scenario (= without climate change) in million euros 2008 (for comparison: GDP 2050 = 555 billion euros 2008)

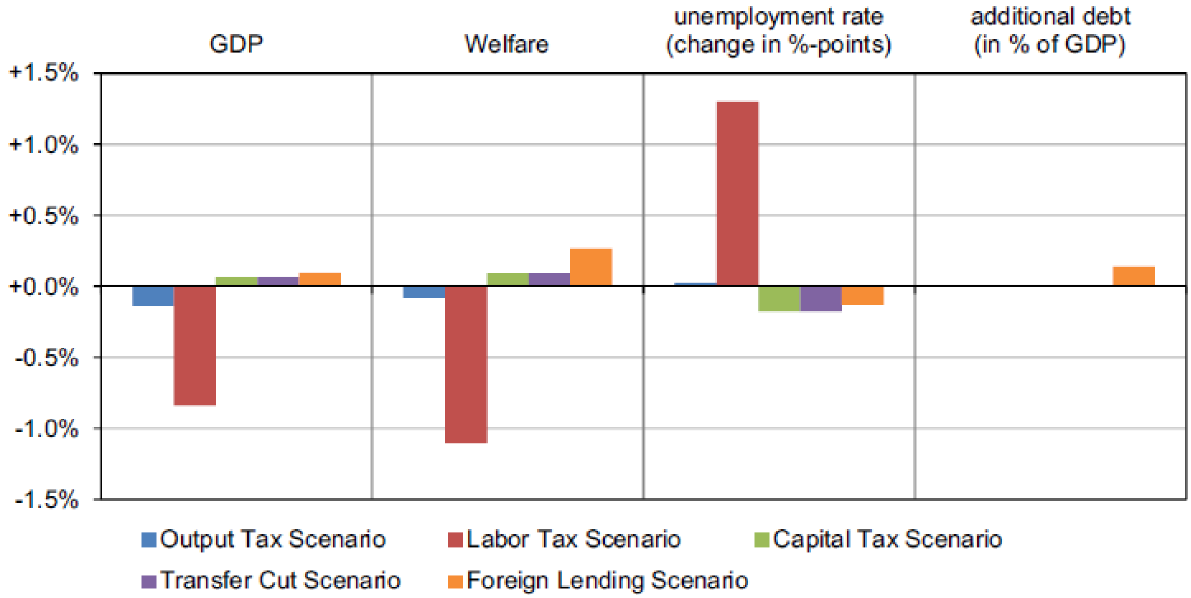


Note: The reduced government consumption does not reflect a positive impact of climate change. It is imposed in this non-counterbalancing scenario that debt-to-GDP ratio remain constant despite reduced fiscal revenues and increased public expenditure for unemployment benefits.
Source: Bachner and Bednar-Friedl (2019)

The reduction of fiscal revenues is somewhat below 600 million euros and the increase of public expenditures (abstracting from the reduction of government consumption imposed to stabilize the debt-to-GDP ratio) is about the same magnitude. The authors thus underline the importance of studying both sides of the budget. Overall, the study finds for 2050 a negative impact on public finances: it yields a reduction in non-climate government consumption by − 1.4%.

Since the cost of climate change may be borne not solely by a reduction of non-climate government consumption, the authors analyse counterbalancing instruments to ensure fiscal stability such as increase of tax rates (output tax, labour tax or capital tax), cutting transfers or borrowing from foreign countries (foreign lending is the unique scenario in which the debt ratio is not constant). While all of these instruments are set in such a way that public service provision is kept at the baseline level (without climate change), the instruments lead to significantly different effects in terms of government revenues and expenditures, while also having different effects on welfare, GDP and employment. The figure below shows the impact of each counterbalancing instrument on selected macro indicators. Labour tax fares much worse than the other instruments considered.

Figure 12. Effects on selected macro indicators, for the five counterbalancing scenarios in 2050



Note: Effects are given in %-point difference between No-Counterbalancing (relative to baseline) and the counterbalancing scenarios (relative to baseline)
Source: Bachner and Bednar-Friedl (2019)

Assessment

It is an interesting feature of this paper that it goes beyond quantifying the impact of climate change on public expenditures and fiscal revenues but also studies the consequences of various ways of counterbalancing this negative fiscal impact. Without counterbalancing, public expenditures that are not related to climate change must be reduced by 1.4% by 2050. If this is feasible, no other measure is necessary. If on the contrary that amount has to be fully counterbalanced, the study suggests not to increase labour tax. The authors explain that “The reasons for this unfavorable effect in case of a higher labor tax is that unemployment and hence expenditures on unemployment payments increase, which reduces the scope for government demand and has overall strongly negative consequences for GDP and welfare.” According to the authors, the increase of labour tax leads to more unemployment because higher labour taxes dis-incentivize employing labour, thereby increasing unemployment and unemployment payments by the government. The reason that a tax on labour dis-incentivize employing labour (rather than merely leading to passing part of that tax on to labour through a decrease in wages) is that there is a minimal wage. It seems however that this effect could be cancelled by adapting the minimal wage.

The impact of climate change on unemployment is the other main innovation of this paper. As mentioned in our chapter 3, it is not self-evident that climate change will have an impact on unemployment (beyond a transitory increase of frictional unemployment if the change in the structure of the economy is not well anticipated). But an unemployment rate that is already high in the absence of climate change points to some causes: market failures or side effects of government policies. It makes sense to study how these causes interact with climate change. According to this study, the impact through unemployment is one of the major channels by which climate change has a fiscal impact (see figures 10 and 11 above). This would deserve more scrutiny.

4.5. Summary of chapter 4

Fiscal sustainability reports tend to focus on the future challenge of population ageing. Lack of quantitative estimates of the economic impact of climate change make it difficult to quantify its fiscal impact. A qualitative discussion is however useful and possible. The Fiscal Risks Report for UK (OBR, 2019), the Debt Sustainability Monitor of the European Commission (European Commission, 2020) and the Report on the Long-Term Sustainability of Public Finances in Switzerland (FDF, 2016) are good examples. A complete quantitative assessment of the fiscal impact of climate change is currently not feasible. A rough quantification in selected sectors can, however, be attempted, such as the preliminary assessment for the US (OMB, 2016). Studies made for Germany Infras/Ecologic (2009) and Austria Bachner and Bednar-Friedl (2019) show that quantitative assessment can provide an indicative picture, even if it remains incomplete and uncertain.

The estimates of expected quantitative impacts tend to be rather small, when compared for example to the impact of demographic change. However, two things must be kept in mind. Firstly, many important risks remain unexplained and unquantified, because their damage potential cannot be quantified or the probability that they occur is not known (e.g. extreme weather events are difficult to model, even more so for the risk of regional and global instability due to conflict and migration or the possibility of abrupt trigger effects in the climate system). Our current understanding of the fiscal risks of climate change is nascent, limited in scope, and subject to significant uncertainty. Secondly, the countries for which we are able to present first studies likely belong to a group of countries that are less affected by climate change than many others (see groups of countries in OECD, 2015). Taking these caveats into account, climate change is an important risk to the sustainability of public finances.

Conclusion: The way forward

Climate change is a big challenge that also has implications for fiscal policy. Fiscal policy has a role to play in mitigating climate change and adapting to it. Reciprocally, climate change will have an impact on public budgets on both the expenditure side and the revenue side. Integrating fiscal impacts of climate change into fiscal reports is important in this setting. This means integrating its short-term impact into the budget process. As argued in this paper, it also means integrating its long-term impact into fiscal sustainability report or similar fiscal publications.

As a first step, the long-term fiscal impact of climate change may be integrated into official fiscal reports merely qualitatively and briefly. Even so, it at least puts climate change on the long-term fiscal radar screen. It gives first indications for deciding about mitigation and adaptation policies, and for assessing if long-term fiscal sustainability may be at peril. The fiscal impact of climate change should ideally be quantified. It is however currently not feasible to get the whole quantitative picture with a decent degree of precision. First steps can, however, be taken to go beyond a qualitative assessment, even if they are initially limited to selected channels that are easier to quantify. This paper provides a few examples that show the way.

Annex A. The Swiss example

Under the Paris Agreement on Climate Change, Switzerland has undertaken to halve its GHG emissions by 2030 compared with 1990 levels. The Federal Council aims for zero net emissions by 2050 (this is an indicative target). This climate target should ensure that Switzerland makes its contribution to limiting global warming to less than 1.5 degrees. In Switzerland, CO_2 emissions from transport, buildings and industry can be reduced by up to 95 per cent by 2050 through technologies that are already available and by using renewable energy sources. There is also potential for reducing greenhouse gases, particularly the methane and nitrous oxide produced by agriculture. In addition, the reduction of emissions produced in other countries will be part of the strategy. Alongside natural CO_2 sinks (such as forests and the soil), technologies that permanently remove greenhouse gases from the atmosphere and store them are to be used in future to offset the remaining emissions. The Federal Office for the Environment is working with other federal offices to draw up the 2050 climate strategy, which the Federal Council plans to finalize by December 2020.

The most pressing fiscal-policy issues related to climate change are linked to mitigation. There is a CO_2 tax at 96 CHF per ton CO_2 (1 CHF is about 1 $), which is high in international comparison. This tax rate could increase to 120 CHF without change of the current law. This CO_2 tax is, however, limited to fossil energy used for heating. There are no CO_2 taxes on fossil energy used for transport (although other specific taxes are levied on it). A question that arises in the short term is whether the law should be modified to increase the maximum CO_2 tax rate and whether to extend the CO_2 tax to fossil energy used for transport. Two thirds of the revenues from the CO_2 tax are redistributed to the population (per capita) and to firms. Subsidies for mitigation (energy efficiency and renewable energy) are financed by a third of the revenues from the CO_2 tax and by revenues from a tax on electricity. Since the polluter-pays principle is applied, these subsidies do not interact with the rest of the budget. An issue that will arise in the medium term is how to deal with the fall in revenues from the specific tax on mineral oil used for transport (these revenues are partly used to finance roads). This fall is due to a decline in consumption which is expected to continue as the share of electric vehicles increase. One option would be to replace this tax by a tax per kilometre (mobility pricing) which would depend on the characteristics of the vehicle (which are a proxy for the impact on infrastructures and for externalities), and possibly on place and time in order to manage traffic congestion. Finally, public expenditures for adaptation seem to be more of a medium to long-term issue. The question will arise to which extent these expenditures should be paid at the federal, cantonal or municipal level.

The "Report on the Long-Term Sustainability of Public Finances in Switzerland" has been published every four years since 2008.[3] The latest version was published in 2016, with a time horizon to 2045 (FDF, 2016). The Federal Ministry of Finance is currently working on the next issue, due to be published in spring 2020. The projections method corresponds to international standards as applied e.g. by the European Commission, the US, the UK and Germany. The projections take into account future demographic developments, using alternative scenarios for migration and productivity to estimate their impact on expenditure and debt for different levels of government. The report provides an overview of the financial position of all levels of government and their long-term perspectives for the impact of demographic changes on public finances. The assessment includes scenarios for the development of demographic-dependent

[3] Additional in-depth assessments are undertaken by the Federal Finance Administration, including healthcare expenditure projections that are produced every four years since 2008 (Brändle and Colombier, 2017) and an analysis of the effects of budgetary targets on healthcare expenditures in different countries (Brändle et. al., 2018). In 2018, the Federal Finance Administration also tried to estimate the impact of immigration on public finances by analyzing the sparse empirical literature on that topic for Switzerland (Bruchez, 2018).

expenditures over the medium-term (up to 2030) and the long-term (up to 2045) including long-term perspectives of expenditure projections for health care (FDF 2016). For the first time, the 2016 report included a box with a first rough qualitative presentation of possible impacts of climate change on public budgets.

Box Error! No text of specified style in document..1. Climate change

Climate change implies not only a rise in temperature, but also an increase in the frequency of extreme weather events. Estimates exist concerning the impact of climate change on the Swiss economy.(a) However, they are shrouded in uncertainty. Moreover, the impact for the public finances has not yet been evaluated for Switzerland.(b) Nevertheless, an impact can be expected via the following channels:

Prevention of climate change

- Public sector expenditure to examine the phenomenon of climate change
- Public sector expenditure to reduce greenhouse gas emissions
- Purchase of foreign certificates to achieve the objectives concerning CO2 emissions

Damage remediation and adaptation

- Public sector expenditure to protect villages, infrastructures, ecosystems, etc. against the growing dangers caused by climate change
- Repair of the damage that could not be avoided (e.g. reconstruction of transport infrastructure destroyed by a landslide)

International commitment

- Contributions to international climate funds and assistance for countries affected by climate change (including the hosting of climate refugees)

Impact on receipts

- Reducing greenhouse gas emissions implies a reduction in the consumption of fossil fuels; this leads to a decline in mineral oil tax receipts
- Insofar as it hampers GDP growth, for example via a reduction in exports to countries impoverished by climate change, climate change will adversely affect the tax base and thus public sector revenue
- Insofar as climate change brings about innovations in the area of green technologies, this economic sector's growth could partly offset the decline in tax receipts

Climate change will thus have a negative impact on public finances by tending to increase expenditure and reduce receipts. If this expenditure is preventive in nature, it will make it possible to avoid even greater expenditure.

(a) See for example DETEC (2007) and OcCC (2007). A new study on the economic costs of climate change is currently being drawn up by the Swiss Federal Institute of Technology Lausanne (EPFL).

(b) In contrast, Infras and Ecologic (2009) are examining the impact for Germany's public finances.

Source: FDF (2016), p. 27

Climate change is expected to have a negative impact on Swiss public finances. The main channels are: prevention of climate change, damage remediation and adaptation, international commitment, and impact on receipts. The 2020 sustainability report will contain a somewhat larger section about climate change, but remain qualitative.

The EPFL published an assessment of the economic impacts of climate change for Switzerland commissioned by Federal Office for the Environment in 2017. This report summarizes the results of a research program that seeks to estimate the possible costs of climate change for Switzerland at the horizon of 2060. It builds on the previous literature (see their section 1.3 for a description of this literature), in particular studies that were made in 2007, but also new climate scenarios and new impact studies that have been published since then. EPFL (2017) goes beyond this literature with a more comprehensive quantitative assessment. It uses the last scenario of the evolution of the Swiss population from the Federal Statistical Office, but extends its time horizon from 2045 to 2060. It follows a general equilibrium approach that accounts for the fact that sectors compete for factors of production and that the outputs of some sectors might serve as intermediate inputs for other sectors, the impact of climate change on one sector of the economy might have noticeable effects on related sectors. International impacts are also crucial for the analysis. The study has a special focus on six areas: health, buildings and infrastructure, energy (hydropower included), water management, agriculture, and tourism.

EPFL (2017) finds a net annual damage of climate change in 2060 of about 2.8 billion CHF of 2008 or 0.43% of total consumption (this includes the monetization of excess premature deaths). The domestic impacts of average temperature change are dominated by detrimental effects of high temperatures on human mortality and labour productivity. The related costs are only partially compensated for by positive impacts, mostly by savings in heating needs and new opportunities for summer tourism. The authors underline that "there might be further international impacts that could be economically important for Switzerland: Climate change could spawn international conflict and migration and reduce trade. This could impact the Swiss labour market, trade volumes and terms of trade, as well as financial flows between the Swiss banking system and the rest of the world. These impacts are very difficult to project and quantify, and deserve more attention. Furthermore, the reinsurance sector, which is prominent in Switzerland, is affected by extreme weather events around the world. […] uncertainties about the overall impact of climate change are still enormous. Especially, the full consequences of future extreme weather events remain unknown. […] the main issue with climate change are potentially increased risks associated with extreme weather events such as storms, heavy precipitation (floods and mudslides), heavy snowfall (avalanches), and hail. Climate change may alter both the frequency and the intensity of such events. It is, however, especially difficult to scientifically substantiate that this will be the case. While it is difficult to simulate expected average changes of the climate, it is even far more difficult to simulate expected changes in extreme weather events. […] it would be incorrect to assume considerable additional damages to buildings and infrastructure as long as scientific confirmation is missing that these risks have to be expected to increase due to climate change. […] Given that many important – and predominantly negative – risks are not taken into account […], we are aware that there is limited value in presenting aggregate numbers of our simulations for Switzerland".

The following table summarizes the economically relevant influences of climate change in Switzerland. It also shows the sign and the importance of the various effects and indicates which potentially important effects have not been simulated due to data constraints.

Table Error! No text of specified style in document..1. Overview of economically relevant influences of climate change in Switzerland

	average temperature change	change in precipitation patterns	extreme weather events	influences from abroad
health	cardiovascular, respiratory and vector-borne diseases, mortality, reduced labor productivity		cardiovascular, respiratory and vector-borne diseases, mortality, reduced labor productivity	reduced labor productivity abroad influences terms of trade
buildings & infrastructure	heat-related and frost-related damages, permafrost melting		floods, mudslides, storms, hail, heat, frost	
energy	space heating and cooling, cooling for thermal electricity generation plants	runoff changes influence hydropower, water availability for cooling of thermal electricity generation plants	energy infrastructure: floods, mudslides, storms, hail, heat, frost	European electricity prices
water management		need for irrigation, lower ground water level	drought: irrigation, ground water level, drinking water quality	
agriculture	longer growth periods, heat stress, pests	need for irrigation	losses due to drought, heavy precipitation, heat, frost	higher prices for imported grains & oilseeds
forestry	longer growth periods, heat stress, pests	dry conditions	storm, heat waves, droughts, forest fires	timber price
ecosystems	migration of species, biodiversity		stress and damage to habitat and creatures	migration of species
tourism	reduced snow cover, shift from winter to summer tourism	reduced snow cover, days of sun	damage to alpine infrastructure	international tourism flows, terms of trade
other		water transport		immigration, international conflict, trade volumes and terms of trade, financial flows, reinsurance payments
legend	positive effect			
	important positive effect			
	negative effect			
	important negative effect			
	effect which has not been simulated due to rather low economic importance			
	potentially important effect which has not been simulated due to data constraints			

Source: EPFL (2017)

References

Auffhammer, M. (2018): Quantifying Economic Damage from Climate Change, Journal of Economic Perspectives 32(4):33.52, https://pubs.aeaweb.org/doi/pdfplus/10.1257/jep.32.4.33

Bachner, G., Bednar-Friedl, B. (2019): The Effects of Climate Change Impacts on Public Budgets and Implications of Fiscal Counterbalancing Instruments, Environmental Modeling and Assessment 24/2, p. 121-142, https://doi.org/10.1007/s10666-018-9617-3

Bachner, G., Bednar-Friedl, B., Knittel, N. (2019): How does climate change adaptation affect public budgets? Development of an assessment framework and a demonstration for Austria, Mitigation and Adaptation Strategies for Global Change, 2019, vol. 24, issue 7, 1325-1341. https://link.springer.com/article/10.1007/s11027-019-9842-3

Bank of England (2015): Breaking the Tragedy of the Horizon – climate change and financial stability, Speech given by Mark Carney, Governor of the Bank of England, Chairman of the Financial Stability Board, Lloyd's of London, 29 September 2015, https://www.bankofengland.co.uk/speech/2015/breaking-the-tragedy-of-the-horizon-climate-change-and-financial-stability

Batten, S. (2018): Climate change and the macro-economy: a critical review, Bank of England Staff Working Paper No. 706.

BIS (2020): The Green Swann - Central banking and financial stability in the age of climate change.

BMF (2016): Vierter Bericht zur Tragfähigkeit der öffentlichen Finanzen, Bundesministerium der Finanzen, Berlin.

Brändle, T., Colombier, C. (2017): Healthcare expenditure projections up to 2045, FFA Working Paper 21, Federal Finance Administration, Bern.

Brändle, T., Colombier, C., Baur, M., Gaillard, S. (2018): Budgetary targets for growth in healthcare expenditure: selected experiences and findings for Switzerland, FFA Working Paper 22, Federal Finance Administration, Bern.

Bruchez, P.-A. (2018): Impact of Immigration on Public Finances, FFA Working Paper 24, Federal Finance Administration, Bern.

Burke, M., Hsiang, S. M., Edward, M. (2015): Global non-linear effect of temperature on economic production. Nature. Nov; 527(7577):235. https://www.nature.com/articles/nature15725
Additional material is available at the following link: https://web.stanford.edu/~mburke/climate/

CBO (2019): The 2019 Long-term Budget Outlook, Congress of the United States, Congressional Budget Office, Washington.

CEPS and ZEW (2010), The fiscal implications of climate change adaptation. Part I and II. https://ec.europa.eu/economy_finance/publications/external_publishers/ex_study1_en.htm

Committee on Climate Change (2019): Net Zero: The UK's contribution to stopping global warming. https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

Cust J., Manley, D., Checchinato, G. (2017): Unburnable Wealth of Nations, Finance & Development, March 2017, Vol. 54, No. 1. https://www.imf.org/external/pubs/ft/fandd/2017/03/cust.htm

Delpiazzo, E., Parrado, R. (2015): Analyzing the coordinated impacts of climate policies for financing adaptation and development actions (no. RP0276) Euro-Mediterranean Center for Climate Change Fundation, https://www.gtap.agecon.purdue.edu/resources/download/7978.pdf

Ecoplan (2012), Volkswirtschaftliche Auswirkungen einer ökologischen Steuerreform - Analyse mit einem berechenbaren Gleichgewichtsmodell für die Schweiz, Schlussbericht, Bern, 12.09.2012. https://www.efv.admin.ch/dam/efv/de/dokumente/projekte/lenkungssystem/ext_forschungsberichte/Gutachten_ECOPLAN_d.pdf.download.pdf/Gutachten_ECOPLAN_d.pdf

Ecoplan/Sigmaplan (2007): Auswirkungen der Klimaveränderung auf die Schweizer Volkswirtschaft (nationale Einflüsse), commissioned by the Federal Office for the Environment (FOEN) and Swiss Federal Office of Energy (SFOE), Bern.

EPFL (2017): Assessing the impacts of climate change for Switzerland, Final Report, commissioned by Federal Office for the Environment (FOEN), Lausanne/Bern. https://infoscience.epfl.ch/record/252804/files/EPFL_-_Assessing_the_impacts_of_climate_change_for_Switzerland.pdf?version=1
See also "Cost and benefits of climate change in Switzerland", published in 2019 in Climate Change Economics 10(2), pp.1-34
https://www.researchgate.net/publication/331659494_Cost_and_benefits_of_climate_change_in_Switzerland_published_in_Climate_Change_Economics_102_pp1-34

European Commission (2020): Debt Sustainability monitor 2019, European Commission, Institutional Paper 120, January 2020.
file:///O:/Oeab-daten/131%20OECD/Green%20Budgeting/Literatur%20International/EC%20(2019).pdf

European Commission (2019): Fiscal Sustainability Report 2018, Vol. 1 & 2, Institutional Paper 094, Luxembourg.

European Commission (2018a): The 2018 Ageing Report: Economic and Budgetary Projections for the 28 EU Member States (2016-2070), Institutional Paper 079, Luxembourg.

European Commission (2018b): A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773

FDF (2016): Report on the Long-Term Sustainability of Public Finances in Switzerland, Federal Department of Finance, Bern.

FOEN (2017): Klimabedingte Risiken und Chancen – Eine schweizweite Synthese, Federal Office for the Environment, Bern.

Hausfather, Z. (2018), Analysis: Why the IPCC 1.5C report expanded the carbon budget, Carbon Brief, 8 October 2018.
https://www.carbonbrief.org/analysis-why-the-ipcc-1-5c-report-expanded-the-carbon-budget

Hausfather Z., Drake H. F., Abbott T., Schmidt, G. A. (2019): Evaluating the performance of past climate model projections, Geophysical Research Letters.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085378

Heal, G., Millner, A. (2014): Uncertainty and Decision Making in Climate Change Economics, Review of Environmental Economics and Policy, volume 8, issue 1, 2014, pp. 120–137.
https://www0.gsb.columbia.edu/faculty/gheal/EnvironmentalEconomicsPapers/REEP%20uncertainty%20published.pdf

HM Government (2017): UK Climate Change Risk Assessment 2017.

IMF (2019a), How to mitigate climate change, Fiscal Monitor.

IMF (2019b), Fiscal Policies for Paris Climate Strategies—from Principle to Practice, IMF Policy Paper No. 19/010, May.

IMF (2019c), The Economics of Climate, Finance & Development, December 2019. https://www.imf.org/external/pubs/ft/fandd/2019/12/pdf/fd1219.pdf

IMF (2008) The Fiscal Implications of Climate Change, Washington.

Infras/Ecologic (2009): Klimawandel: Welche Belastungen entstehen für die Tragfähigkeit der Öffentlichen Finanzen, Gutachten i.A. des Deutschen Bundesministeriums für Finanzen, Berlin.

Paper: https://www.ecologic.eu/sites/files/project/2013/Endbericht_FINAL_Klimawandel.pdf

Summary (inclusive an English summary): https://www.infras.ch/media/filer_public/65/41/65415ae5-8060-4cea-9176-c34cf47b857a/kurzfassung_final_281009.pdf

Infras/Ecologic/Rütter and Partner (2007): Auswirkungen der Klimaänderung auf die Schweizer Volkswirtschaft (internationale Einflüsse), commissioned by the Federal Office for the Environment (FOEN) and Swiss Federal Office of Energy (SFOE), Bern.

IPCC (2019): Climate Change and Land - An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems - Summary for Policymakers https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf

IPCC (2018): Global Warming of 1.5°C, Special Report. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf See also the related IPCC press release https://www.ipcc.ch/site/assets/uploads/2018/11/pr_181008_P48_spm_en.pdf

IPCC (2014): Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf

Kaya, Y., Yokoburi, K. (1997): Environment, energy, and economy: strategies for sustainability. Tokyo: United Nations Univ. Press.

Krogstrup, S., Oman, W. (2019): Macroeconomic and Financial Policies for Climate Change Mitigation: A Review of the Literature, IMF Working Paper 19/185.

Leppänen, S., Solanko, L., Kosonen, R. (2017): The impact of climate change on regional government expenditures: evidence from Russia, Environmental and Ressource Economics 67/1, p. 67-92, https://doi.org/10.1007/s10640-015-9977-y

Lis, E.M., Nickel, C. (2010): The impact of extreme weather events on budget balances, International Tax and Public Finance 17(4), p. 378-399, https://doi.org/10.1007/s10797-010-9144-x

Meier, R. (1998): Sozioökonomische Aspekte von Klimaänderungen und Naturkatastrophen in der Schweiz, Final Report of the Project NFP31, Zurich.

NGFS (2019): A call for action – Climate change as a source of financial risk, Network for Greening the Financial System, First Comprehensive Report, April 2019.

Nordhaus W. (2018a): "Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies," American Economic Journal: Economic Policy, American Economic Association, vol. 10(3), pages 333-360, August. https://pubs.aeaweb.org/doi/pdfplus/10.1257/pol.20170046

Nordhaus, W. (2018b): Nobel Prize lecture "Climate Change: The Ultimate Challenge for Economics" https://www.nobelprize.org/prizes/economic-sciences/2018/nordhaus/lecture/

Nordhaus, W. (2013): The Climate Casino: Risk, Uncertainty, and Economics for a Warming World, Yale University Press, New Haven.

Nordhaus, W. (2011): The Economics of Tail Events with an Application to Climate Change, Review of Environmental Economics and Policy, volume 5, issue 2, summer 2011, pp. 240–257. http://econdse.org/wp-content/uploads/2014/02/WDN_TailEvents_REEP_2011_Nordhaus.pdf

OBR (2019): Fiscal Risk Report, Office for Budget Responsibility, London. https://obr.uk/frr/fiscal-risks-report-july-2019/

OBR (2018): Fiscal sustainability report, Office for Budget Responsibility, London.

OECD (2019a): Fiscal Resilience to Natural Disasters - Lessons from Country Experiences, Paris. https://www.oecd-ilibrary.org/governance/fiscal-resilience-to-natural-disasters_27a4198a-en

OECD (2019b): Accelerating Climate Action: Refocusing Policies through a Well-being Lens, Paris. https://doi.org/10.1787/2f4c8c9a-en

OECD (2015a): The Economic Consequences of Climate Change, Paris. https://www.oecd.org/env/the-economic-consequences-of-climate-change-9789264235410-en.htm

OECD (2015b): The Distributional Effects of Energy Taxes, Paris. https://www.oecd-ilibrary.org/docserver/5js1qwkqqrbv-en.pdf?expires=1580470673&id=id&accname=guest&checksum=8AEC6DA3C1C71C64AC949BD3A844101B

OECD and ITF (2019): Tax Revenue Implications of Decarbonising Road Transport: Scenarios for Slovenia, OECD Publishing, Paris, https://doi.org/10.1787/87b39a2f-en

OMB (2016): Climate Change: The Fiscal Risks Facing the Federal Government – A Preliminary Assessment, Office of Management and Budget, Washington. https://obamawhitehouse.archives.gov/sites/default/files/omb/reports/omb_climate_change_fiscal_risk_report.pdf

Osberghaus, D., Reif, C. (2010): Total costs and budgetary effects of adaptation to climate change: an assessment for the European Union, ZEW Discussion Paper (10-046). https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1649452

SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP (2019): The Production Gap - The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C.

Stern, N. (2008): The Economics of Climate Change, American Economic Review: Papers & Proceedings 2008, 98:2, 1-37.

Stern, N. (2007): The Economics of Climate Change: The Stern Review, Cambridge University Press, Cambridge/New York. https://www.cambridge.org/core/books/economics-of-climate-change/A1E0BBF2F0ED8E2E4142A9C878052204

Swiss Confederation (2014): Anpassung an den Klimawandel in der Schweiz, Aktionsplan 2014-2019, Federal Office for the Environment (FOEN), Bern.

Think (2011): The impact of climate and energy policies on the public budget of EU member states, Final Report, June 2011.

Weitzman, M. L. (2014): Fat Tails and the Social Cost of Carbon, American Economic Review: Papers & Proceedings 2014, 104(5): 544–546. https://scholar.harvard.edu/files/weitzman/files/aer.104.5.544fattailsandthesocialcostofcarbon.pdf

Weitzman, M. L. (2011): Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change, Review of Environmental Economics and Policy, volume 5, issue 2, summer 2011, pp. 275–292. https://scholar.harvard.edu/files/weitzman/files/fattaileduncertaintyeconomics.pdf

Weitzman, M. L. (2009): On modeling and interpreting the economics of catastrophic climate change. Review of Economics and Statistics 91(1): 1-19. https://dash.harvard.edu/bitstream/handle/1/3693423/Weitzman_OnModeling.pdf

World Bank (2010): The Cost to Developing Countries of Adapting to Climate Change: New Methods and Estimates, Washington.

Endnotes

[1] Producing electricity with nuclear energy rather than fossil energy reduces CO_2 emissions. In this sense, nuclear energy is a mitigation instrument. The Bonn Agreement of 2001 stipulates, however, that parties cannot use (more exactly "are to refrain from using") nuclear energy to generate credits from investment projects under Joint Implementation or the clean development mechanism.

[2] NDCs are now consistent with 3°C warming by 2100. See SEI et al. (2019).

[3] A mitigation tax should be as comprehensive as possible. Motor oil should be taxed as well as heating oil, oil used as raw material in plastic as well as oil used for energy.

[4] See CEPS and ZEW (2010), for a discussion of public adaptation (involving the intervention of the state) versus private autonomous adaptation (unaided and unguided actions of private agents).

[5] IMF (2019a) finds that "If no accompanying measures were taken, carbon taxes would be moderately regressive in China and the United States, distribution-neutral in Canada, and moderately progressive in India for a $50 a ton carbon tax in 2030".

[6] For a study of 21 countries, see OECD (2015b). Ecoplan (2012) studies for Switzerland the redistribution impact of various usages of revenues of taxes on CO_2 and electricity, and discusses the efficiency/equity trade-off.

[7] For a deeper discussion see Heal and Antony (2014) and chapter 2 of IPCC (2014).

[8] See Weitzman (2009), Weitzman (2011) and Weitzman (2014), as well as Nordhaus (2011).

[9] If catastrophic risks cannot be eliminated anymore, i.e. the option is merely to make the tail less fat (reducing the probability of a catastrophic event could be very useful even if the expected cost still remains infinite), then it might be the case that mitigation reduces expected costs by only a finite amount. In this case, cost-benefit analysis could be carried out despite fat tails.

[10] A fiscal impact of climate of 10% of public expenditures relative to a scenario without climate change could be compensated for by a tax increase of the same amount (assuming public spending would be equal to tax revenues in the absence of climate change). This is a large tax increase but would still be compatible with a large increase of free disposable income if this fiscal impact occurs sufficiently far in the future, let say at the end of the century. Let's assume 1% annual growth of GDP. This would more than double the GDP from 2020 to 2100 ($1.01^{80}=2.2$). Let's assume that total public spending in 2020 is one third of GDP and the average tax rate is also one third (33.3%). The free disposable income would be multiplied by 2.2 by 2100 in the absence of climate change. Because of climate change, the average tax rate in 2100 is not 33.3% but 33.3%*1.1=36.6%. Thus, the free disposable income in 2100 is not multiplied by 2.2 but only by 2.2*(100%-36.6%)/(100%-33.3%)=2.1. This remains a big increase. It is a yearly increase of 0.94% instead of 1%. Many other causes could lead to a change of yearly growth of disposable income of merely 0.06%. This computation assumes that climate change does not modify GDP but only public expenditures. Let's assume on the contrary that the fiscal deterioration comes entirely from the revenue side: a 10% decrease of GDP (relative to the no climate change scenario) leads to a 10% decrease in fiscal revenues. Then disposable income will not be multiplied by 2.1 but by 2.1*(100%-10%) which is about 1.9. Still a nice increase. Alternatively, public expenditures not related to climate change could be reduced (relative to the no climate change scenario) to make room for expenditures related to

climate change. This would imply reducing expenditures not related to climate change by 10% in 2100. Those expenditures would not increase yearly by 1% like GDP, but only 0.87%.

[11] See our section 3.3. For a more in-depth discussion, see for example Stern (2008) and OECD (2015a). Concerning more specifically the impact on the financial market, see for example NGFS (2019) and the article "Climate change and financial risk" in IMF (2019c).

[12] IMF (2019a) and Krogstrup and Oman (2019) for example take a broad view on instruments for climate-change mitigation. IMF (2019b) is more focused on fiscal instruments.