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The economic and financial stability repercussions of nature degradation for the Netherlands: Exploring scenarios with transition shocks

A first exploration

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Executive Summary

There is scientific consensus that nature and its vital contributions to prosperity are deteriorating worldwide. We have exceeded six out of the nine planetary boundaries within which humanity is known to live in a safe environment. Against this background, measures are being taken to halt and reverse nature degradation at global, regional, and national levels. Importantly, the UN Global Biodiversity Framework of December 2022, the implementation of the EU Green Deal and European Biodiversity Strategy, and the current nitrogen discussion in the Netherlands bring nature-related risks at the forefront.

This study is a first exploration of the potential economic and financial stability impacts of a set of tail-event scenarios that reflect strong measures taken suddenly in response to nature degradation.[1] We consider four transition risk scenarios, for which we find varying degrees of materiality. We do not focus on physical risk scenarios, with the exception of a scenario of pollination decline, due to methodological limitations. This study is a first, methodological contribution to the analysis of the impact of nature degradation on economic developments and financial stability. To draw policy conclusions from this analysis would require further work.

1. These scenarios are hypothetical. They do not constitute policy advice nor reflect the position of DNB on these matters.

The uncertainty associated with nature-related risks and the exploratory methodologies applied in this study make it challenging to provide a concrete estimate of the economic and financial stability impacts. With this important caveat in mind, from the tail-event scenarios considered, we find that a global scenario of ending explicit fossil fuel subsidies has a negligible impact for the Netherlands. The global tail scenario of ending total—explicit and implicit—fossil fuel subsidies suddenly and fully, and without considering offsetting fiscal stimulus, has a non-negligible peak GDP impact of 3% decline compared to the baseline in year two.[2] By year five, this impact is halved. A Dutch nitrogen scenario where insufficient measures are taken to reduce the nitrogen footprint of agriculture and consequently other sectors are impacted also has a non-negligible economic impact. The peak impact on Dutch GDP is a 1.4% decline in the second year after the shock, when compared to the baseline. In contrast, the scenario of reducing agricultural production sufficiently to tackle the nitrogen problem has a peak GDP impact of 0.7% decline when compared to the baseline. For the other two transition risk scenarios—a global scenario whereby 50% of the Earth is categorized as a protected area in order to protect biodiversity richness, and an EU scenario aimed at disincentivizing the import into the EU of products with a high deforestation footprint—we find very limited macroeconomic impact, likely due to modelling constraints.

2. The definitions of fossil fuel subsidies in the scenarios of this report are based on IMF definitions, which are different from the definitions used in the Dutch Budget Memorandum (see section 2.1, scenario 4). In addition, the tail scenarios considered herein are different from the policy scenarios under discussion at the national level.

An initial assessment of losses for Dutch financial institutions of these scenarios points to limited impact. Preliminary estimations on the credit losses that Dutch banks could suffer under the two scenarios associated with the largest economic impact—the global scenario of ending total fossil fuel subsidies and the Dutch scenario of not taking enough measures to decrease the nitrogen footprint—find limited system-wide capital depletions of 5 to 25 basis points. For insurers and pension funds, only the global fossil fuel scenario has a meaningful impact, with a weighted average loss on the market value of assets of 3% for insurers and 5.3% for pension funds.

The preliminary results seem to suggest that it should be possible to take transition measures without causing a substantial impact on the Dutch economy and financial stability. Specifically, the results point to the possibility of phasing out all explicit fossil fuel subsidies without a substantial economic and financial impact. A more orderly version of our global scenario of ending all global fossil fuel subsidies would likely have a smaller economic and financial impact. In addition, the findings highlight the importance of taking sufficient measures to decrease the nitrogen footprint as a means to avoid a potentially larger economic and financial impact associated with not taking such measures. Individual financial institutions can also proactively mitigate the risks for their portfolios by taking the transition to a nature-positive economy into account.

We highlight four main limitations of this analysis, most of which point to a likely underestimation of the real economic and financial stability impact of nature scenarios. First, all the scenarios analysed are one-dimensional, taking into account only one transition measure. A more realistic (physical or transition risk) nature scenario would be multi-dimensional, i.e. would need to consist of multiple shocks to many of the services that nature offers and/or a broader set of transition measures. As an example, the limited impact for the Netherlands of the Half-Earth scenario is partly due to assumed increases in agricultural production, which would be at odds with the nitrogen scenario of taking sufficient measures to decrease the nitrogen footprint. Second, the use of a computable general equilibrium model to estimate the economic impact of some of these transition risk scenarios likely leads to an underestimation of the short-term stresses, as the model gives by construction an equilibrium result. Third, the many interdependencies and amplifications of climate and broader dimensions of nature point to a need to consider these jointly to fully grasp the severity of climate and nature-related risks. Lastly, the observed heterogeneity of impact on different economic sectors points to a need to also consider the sectoral dimension of financial institutions' potential losses.

By presenting these preliminary results and the methodological challenges and lessons learned, we hope to inform other institutions and central banks that work in this important and challenging area and bring us a step closer to understanding the economic and financial stability repercussions of nature degradation.

1 Introduction

In March 2022, the Network for Greening the Financial System (NGFS) acknowledged that 'nature-related risks, including those associated with biodiversity loss, could have significant macroeconomic implications, and that failure to account for, mitigate, and adapt to these implications is a source of risks relevant for financial stability'. The new UN Global Biodiversity Framework of December 2022, the implementation of the EU Green Deal, and the current nitrogen discussion in the Netherlands bring nature degradation and any measures taken to halt or reverse it to center stage. They also provide a starting point for thinking about transition risk scenarios. This Occasional Study is a first exploration of the potential economic and financial stability impact of a set of transition scenarios that may reflect measures taken in response to nature degradation. We also analyze a niche physical risk scenario.

There is scientific consensus that nature and its vital contributions to prosperity are deteriorating worldwide.[3] Six out of the nine planetary boundaries within which humanity can live in a safe environment—including those related to negative trends in the area of biosphere integrity (genetic diversity and planetary function), climate change, land system change, biochemical flows (nitrogen and phosphorus), fresh water change, and novel entities (e.g. synthetic chemicals and substances) have been exceeded.[4] Still, planetary-scale environmental pressure by humanity continues, leaving ultimate global environmental conditions uncertain.[5] Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes.[6] This could be thought of as an increased susceptibility to physical nature-(and climate-) related risks, i.e the risks stemming from the degradation of nature and the loss of services that we get from nature. Consequently, as a nature-positive transition becomes increasingly pressing, nature-related transition risks also become increasingly likely. These transition risks stem from the misalignment of economic actors with actions aimed at protecting or restoring nature.[7]

The study of nature-related risks beyond climate change as a potential source of economic and financial risk is still nascent. To date, most studies focus on identifying exposures of financial institutions that depend on and/or impact nature. In 2020, the DNB-PBL study *Indebted to Nature* found that 36% of the investment portfolio of Dutch financial institutions (Fis) under analysis was highly or very highly dependent on nature's services. From 2021

3. IPBES, 2019
4. Richardson et al., 2023
5. Richardson et al., 2023
6. Planetary boundaries - Stockholm Resilience Centre. See here.
7. NGFS Conceptual Framework on Nature-related financial risks (2023)

onwards, several central banks followed suit with similar analyses and obtained similar results in their jurisdictions.[8]

To properly assess nature-related financial risks in the face of uncertainty, it is important to identify plausible and severe nature-related hazards (or shocks) and their transmission to the economy, identify the exposures impacted by these shocks, and estimate the vulnerability of these exposures to the shocks.[9] This would allow us to estimate the financial losses that financial institutions would suffer as a result of different nature-related shocks, and therefore conclude on the materiality of these risks to financial stability. A notable global study that uses such a scenario approach to estimate the economic impact of a decline in some of the services we receive from nature is the Worldbank's *The economic case for nature*[10]. In this study, we try to move from a nature-related shock, to economic impact, and then to impact on financial institutions using a series of transition (and one physical) risk scenarios.

We analyze five scenarios: four transition risk scenarios and one physical risk scenario. The *Half-Earth protection* scenario is a global scenario whereby 50% of the Earth is categorized as a 'protected area', with protection focusing on areas where biodiversity is the highest. The *Pollination decline* scenario—the only physical risk scenario we consider here—is a global scenario of a decline in wild pollinators. The *Deforestation tax* scenario is an EU scenario aimed at disincentivizing the import into the EU of products with a high deforestation footprint. The *Ending harmful subsidies* scenario, in

8. Svartzman et al., 2021, Elderson, 2023
9. Svartzman et al. 2021
10. World Bank, 2021

which subsidies harmful to biodiversity are eliminated, has one global and one European dimension. The scenarios on *Nitrogen measures* are specifically for the Netherlands, in which government measures to reduce nitrogen pollution directly impact either the agricultural or the construction sectors.

1.1 Nature loss and scenario analysis

Scenario analysis is useful in order to deal with the inherent uncertainty that surrounds nature degradation.[11] Scenario analysis makes it possible to understand how nature-related risks might materialize in the future. Estimating the economic and financial stability impact of nature-related scenarios is challenging, partly due to the interdisciplinarity of the topic. The fields of natural sciences, economics, and financial risk need to be connected.

As nature-related scenario analysis is a very new field of study, the methodologies used reflect an initial exploration. The explorative nature of the analysis has given us the freedom to try out a number of different methodological approaches in bridging nature and the economy. As such, the methodologies presented herein should be seen as an initial step in trying to grasp the economic and financial repercussions of nature-related scenarios through using the data and models available to us. The results should therefore also be interpreted in that light.

Building nature scenarios involves additional challenges compared to climate scenarios. While climate change and broader nature degradation have much in common, most especially the huge uncertainties about future developments and tipping points and the

11. IPBES, 2019

self-reinforcing interactions between them, they also differ greatly. Nature degradation is multi-dimensional. For climate change, CO_2 emissions and CO_2 pricing are regarded as relatively good metrics for physical and transition risk sources respectively, although they are still subject to debate. For nature, there is no such potential single metric. Rather, there exists a multitude of ecosystems and ecosystem services, and a multitude of ways of measuring them. In addition, nature degradation and the associated biodiversity loss have a strong local nature. This might mean that to describe a nature degraded future or a nature positive future, a multitude of underlying scenarios describing different dimensions of nature degradation and/or a diverse set of policies taken to protect nature would have to be considered in conjunction.

Given the lack of readily-made nature scenarios used for financial stability assessments, in this study we develop and analyze five such scenarios. There is currently a lack of agreed-upon nature scenarios usable for financial stability risk assessments.[12, 13] We use as inspiration for transition risk shocks the targets of the Kunming-Montreal Global Biodiversity Framework[14], the European Green Deal, and the European Biodiversity Strategy. For estimating financial vulnerabilities, we rely on stress-testing models that compute an impact on financial institutions based on (macro)economic projections.

12. The nature scenarios referred to here are shorter-term scenarios used for financial stability risk assessments. These are different from longer-term scenarios used for systemic analysis, an example of which are the long-term scenarios developed by the PBL for the Convention on Biological Diversity outlook.
13. This is in contrast to existing climate scenarios. See NGFS Scenarios Portal
14. Convention of Biological diversity, 2022a

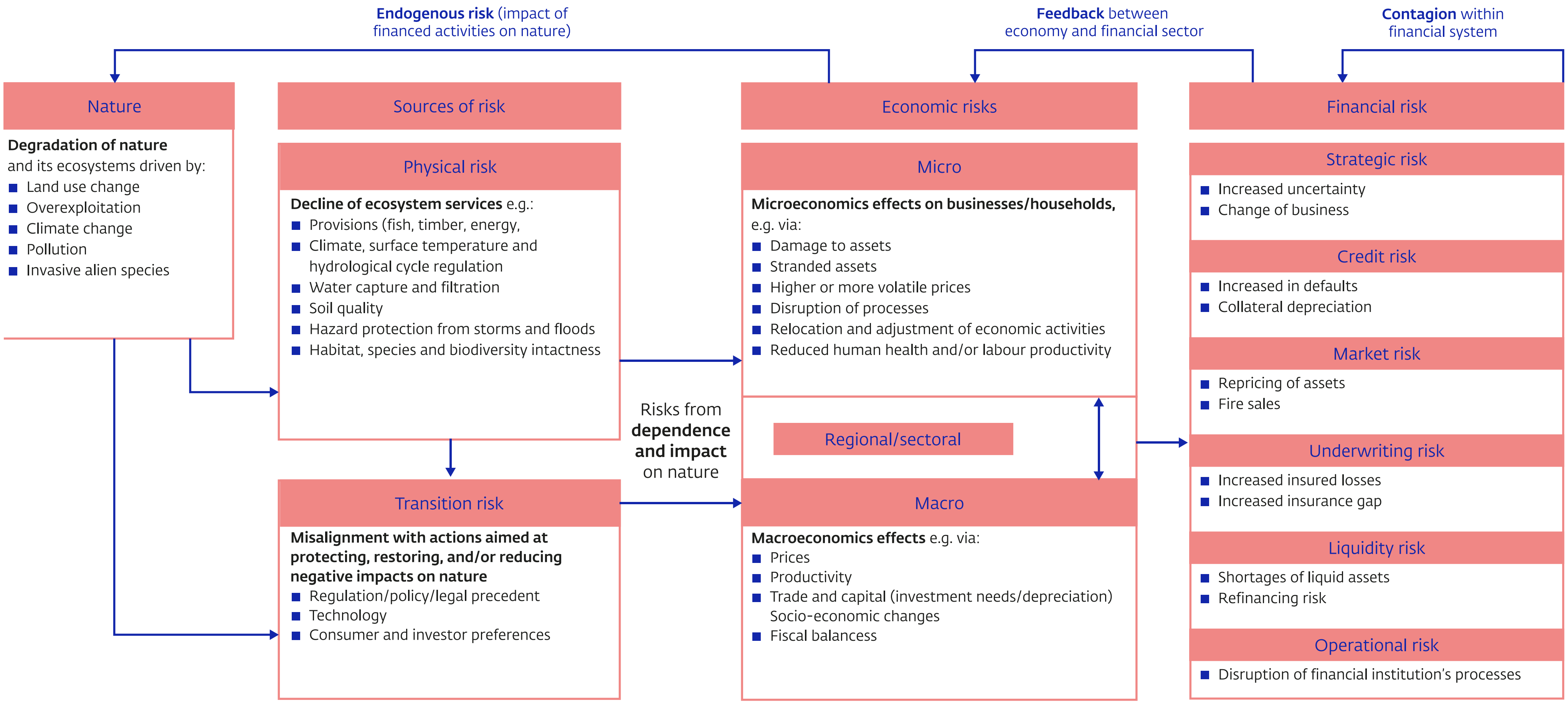
1.2 Nature decline as a financial risk

Economic activities are dependent on nature. Our financial systems—as enablers of these economic activities—are thus exposed to nature degradation and a decline in services we get from nature (ecosystem services). Financial institutions also impact nature through the economic activities they finance, making nature-related financial risks at least partly endogenous. Nature-related physical or transition shocks produce an economic impact that impacts financial institutions through traditional risk categories, such as credit and market risk. (Figure 1)

The interrelation of nature (degradation) with climate change is an additional concern from a financial stability perspective. Nature degradation and climate change reinforce one another. Climate change, currently the second most important driver of biodiversity loss, is set to be the first driver of biodiversity loss if global warming is not limited to 1.5°C.[15] In addition, climate mitigation and adaptation could also amplify broader nature risks.[16] On the other side, nature degradation affects climate change while positive developments in nature can mitigate climate change. This nexus makes the case for joint nature-climate scenarios and risk assessments, which we have done in this study, as considering these risks separately could lead to a severe underestimation of their economic and financial impact.[17]

15. Convention of Biological diversity, 2022b
16. As an example, afforestation programs could focus on rapid tree growth through monoculture plantations that harm native biodiversity.
17. IPBES, 2021

igure 1 Transmission channels of nature-related risks



1.3 Overview of approach

Through scenario analysis, we seek to improve our understanding of the transmission of an array of nature-related (transition and physical risk) shocks to the economy and financial system. The scope of the scenarios varies from global, to European, to national for the Netherlands, largely driven by the jurisdictional applicability of the measures under consideration.

The interdisciplinary nature of the topic, the diversity of the scenarios under analysis, and modelling constraints lead us to use different methodologies for translating a nature-related shock to an economic impact. Please refer to Figure 2 for an overview of the model chain used for each scenario to move from a nature shock to an economic impact and then to a financial impact. Given that the economic impact of nature degradation and policy measures taken to halt it is heterogeneous across economic sectors, we try to reflect this heterogeneity in the economic modelling insofar as possible.

Modelling constraints dictate the choice of scenarios, the way in which these are modelled, and their estimated impact. Section 4 provides an overview of the categories of models used, their limitations, and scope for improvements. Importantly, it has not always been possible to estimate the short-run economic impact of nature-related shocks, even though that is when the strongest disruption materializes. Specifically, for the scenarios modelled through the computable general equilibrium model, it is only possible to estimate the medium to long-run effects which will be less severe since the economy has had time to adjust to the shock.

For the scenarios *Half-Earth protection*, *Deforestation tax*, and *Pollination decline*, we use a Computable General Equilibrium (CGE) model to have a first view of economic impact.[18,19] The model was chosen due to its detailed representation of the different (food) commodity categories needed to be shocked for the *Deforestation tax* and *Pollination decline* scenarios, and its link to other models needed to compute the land use consequences of the *Half Earth protection s*cenario. In order to get a more comprehensive macro-financial scenario that is needed for estimating financial institutions' losses, we apply the price shocks coming from this model as exogenous shocks in a structural model of the global economy[20].[21] The choice for a global model reflects the global scope of these scenarios.

For the global scenario *Ending harmful subsidies* we use a structural model of the global economy to estimate an economic impact. In order to get a view of sectoral heterogeneity, which was not possible for the global scenario, we also include a second harmful subsidies scenario, which looks at sectoral effects. This second scenario only includes the EU-27 Member States, because of data limitations, and uses an Input-Output table to compute direct impacts.

For the Dutch scenarios on *Nitrogen measures*, we use current projections of output decline in the agricultural sector and a potential effect on the construction sector. Given that these initial shocks are sectoral, we use an Input-Output table to translate them to an economy-wide output decline for the Netherlands. Then, to get a broader macro-financial scenario, we use the economy-wide decline

18. See Regional Computable General Equilibrium models: A review—ScienceDirect
19. See The MAGNET Model | MAGNET (magnet-model.eu)
20. Vermeulen, 2018
21. Daniels et al, 2017

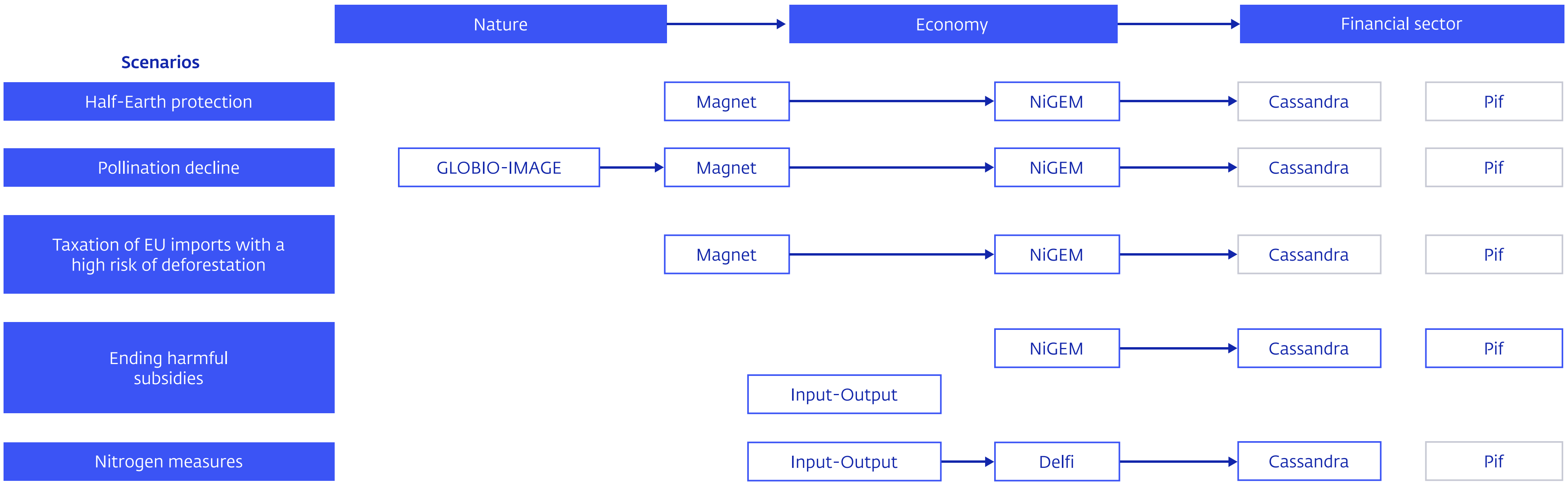
as an input in a semi-structural macroeconomic model of the Dutch economy. This model has a more detailed representation of the Dutch economy, which suits the geographical scope of the scenario.

For all the scenarios, we implement the initial shock fully and suddenly and then trace the results 4 years ahead. The aim of the immediate shock is to simulate a severe scenario, which is particularly useful from a financial stability perspective. In the CGE model this is done in a *comparative static* approach, which does not have a time dimension.[22] We then use (semi) structural economic models to track the results for four years ahead, which corresponds to the timeframe in which most of the impact materializes. This horizon is also the most relevant from a financial sector perspective. Scenarios with longer time horizons require very strong assumptions about the potentially substantial changes that institutions' balance sheets might undergo.

For translating the economic impact into a financial impact for Dutch financial institutions, we use the macro-financial scenarios produced by the economic models in our financial models[23]. Given the uncertainties surrounding economic impacts, this study only sketches a first assessment of implications for financial institutions. More specifically, we focus on the largest risk categories for Dutch financial institutions: increases in credit losses for banks and increases in market risk for insurers and pension funds. We estimate financial losses only for the scenarios that have a significant macroeconomic impact. Whilst doing so, we do not yet distinguish between economic sectors when calculating the losses on institutions' portfolios.

22. Using the comparative static approach, we obtain what we would call *medium-run equilibrium* results, allowing the economy to adjust to the shock under existing production capacities (allowing the total constant capital stock to move across the production sectors). This is in contrast to the dynamic approach, in which production capacity also changes, and which gives us *long-run equilibrium* results.
23. Daniels et al., 2017

Figure 2 The model chain used for each scenario



Notes: DELFI is DNB's semi-structural model of the Dutch economy; NiGEM is a structural model of the global economy; MAGNET is a computable general equilibrium model; Cassandra is DNB's top-down stress-testing model for banks; PIF is a simple model used to calculate the financial impact on pension funds and insurers. The grayed out models are not used to calculate an impact on the financial sector, given that the limited economic impact of these scenarios does not point to an impact on the financial sector.

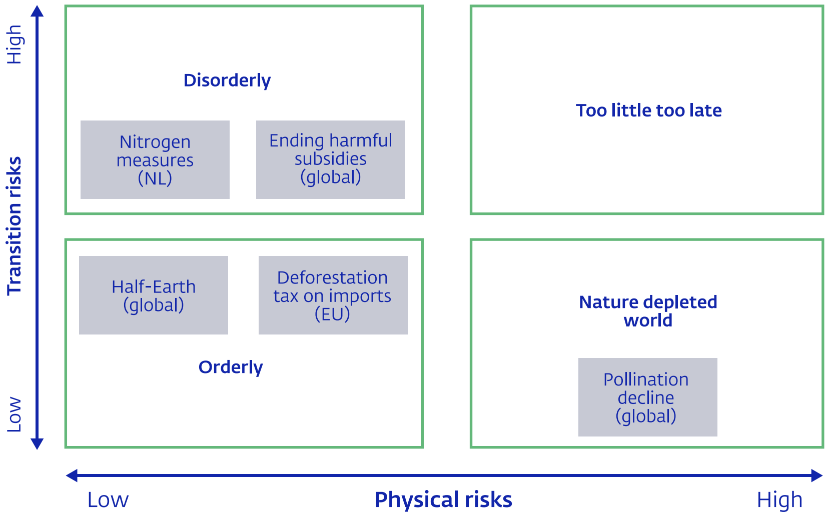
2 Scenarios

In order to grasp the potential financial stability repercussions of nature degradation and of any measures taken to halt it, we need to identify potential sources of transition and/or physical risk and understand how these shocks transmit to the macroeconomy (section 2.1). For the scenarios that produce the most severe economic impact (section 2.1 and 2.2), we then estimate an impact on financial institutions (section 3).

Each transition risk scenario is driven by a policy measure taken to protect nature. The scenarios vary in geographical scope from global to European and national, following the application of the relevant policy measure. All policy measures are implemented fully and suddenly, i.e. without a gradual phase-in period, to emulate a relatively stressful scenario.

We plot the scenarios in an adapted version of the NGFS matrix on the transition and physical risk dimensions of climate scenarios. (Figure 3) **The mapping of scenarios as orderly vs disorderly is driven by the choice of models used for estimating the initial economic impact.** We define disorderly scenarios as those for which we implement the policy suddenly *and* can see the initial impact of the sudden shock into the disorderly transition category. We define orderly scenarios as those for which we implement the policy suddenly *but* can only see the new equilibrium as opposed to the initial impact of the sudden shock into the orderly transition category.[24],[25] The latter is true under the assumption that an orderly announcement and implementation of the measures gives the economy time to price in all expected changes and adjust accordingly, in a manner in which the adjustment reflects the long-term equilibrium. The most stressful scenarios would be those with the highest physical and transition risks, i.e. those in the top right corner of the below figure. These scenarios would consist of a substantial reduction in multiple ecosystem services—physical risk shock—and a package of transition measures being taken too suddenly—transition risk shock. Such scenarios could, however, not be modelled due to methodological limitations. (section 4)

Figure 3 Adaptation of the NGFS matrix on the transition and physical risk dimensions of climate scenarios to nature-related scenarios



24. Note that this categorization is slightly different from another one which would put any sudden shock into the disorderly category and any gradual, incremental shock into the orderly transition category.
25. This is the case for the scenarios run through the CGE model.

2.1 Defining and estimating the economic impact of individual scenarios

Scenario 1—Half-Earth protection

A global scenario whereby 50% of the Earth is categorized as a 'protected area', with protection focusing on areas where biodiversity is the richest.[26] *Dutch agricultural output increases to compensate the decline in production in countries characterized by higher biodiversity, which are more directly impacted by the protected areas. Still, an increase of 17% in the prices of agricultural products decreases consumers' demand for more elastic products and services, resulting in a limited GDP decline compared to the baseline.*

The narrative is inspired by Target 3 of the Kunming-Montreal Global Biodiversity Framework, agreed in December 2022. Target 3 consists of protecting 30% of Earth's most valuable biodiversity hotspots.[27] This is an intermediate step to the long-term goal of around 50% protection of the Earth, which is the goal we use for this scenario.[28]

The expansion of protected areas puts pressure on the availability of land for human use. As a consequence, agricultural production and forestry intensify elsewhere in order to fulfil the population's increasing needs for food and biological resources. The adjusted higher productivity is driven by intensification of other inputs, i.e. by substitution of land by fertilizer, labor, and/or capital. In the longer

26. For more information, see Kok et al., 2023 and and Immovilli & Kok., 2020
27. Convention on Biological Diversity, 2022c
28. The new Planetary Boundaries consider a protection of 50 % to 60% (likely slightly less than 60%) of Earth as key to a sustainable and just transition.

term, technological innovations can partially mitigate the impact, but this takes time to materialize.[29]

The implementation of the measure is done in a computable general equilibrium model, MAGNET[30]. Maps that designate which biodiversity-rich areas would need to be protected until the Half-Earth protection goal is reached are used in the IMAGE-GLOBIO integrated assessment modelling framework.[31,32] The impact of these maps is to restrict the available land for agriculture. Agricultural expansion is also the main input of the model and also the main driver of biodiversity loss globally. The most negatively impacted countries would be those with the largest biodiversity hotspots, e.g. Brazil, India, and Malaysia.

We run this scenario twice, once only with the goal of 50% protected areas, and once in combination with a tax on fertilization that is imposed at the EU level. Such a tax is calibrated to roughly reflect the 20% decrease in fertilizer use foreseen in the EU's Farm to Fork Strategy.[33] The implemented tax rate is therefore a 200% ad valorem tax, added on both domestic and imported intermediate use of all fertilizers.

In MAGNET, the shock is implemented globally in a comparative static manner. This means that 50% protection is implemented suddenly and fully.

29. Immovilli & Kok, 2020
30. See The MAGNET Model | MAGNET (magnet-model.eu)
31. See IMAGE—Integrated Model to Assess the Global Environment | PBL Netherlands Environmental Assessment Agency
32. Kok et al., 2020
33. Wesseler, 2022

The macroeconomic impacts generated by the CGE model are highly heterogeneous across countries and sectors. While the Netherlands is not impacted on an aggregate level, agricultural production increases. (Figure 4a) In the Netherlands, 24%[34] of the country already is a protected area with policies in places to increase this to 27%. Further protection is not foreseen by the model given the limited remaining natural areas in the country[35]. Hence, the Netherlands seems to benefit from an economic perspective from this scenario, as its high competitiveness allows it to better compete with other countries that are most impacted by the protection of biodiversity-rich areas. This is the reason agricultural production increases in the Netherlands by more than 9%, while it decreases in other jurisdictions in which large parts of the country will have to be protected to preserve biodiversity (e.g. the largest decrease of 41% in Indonesia in the Half-Earth scenario).

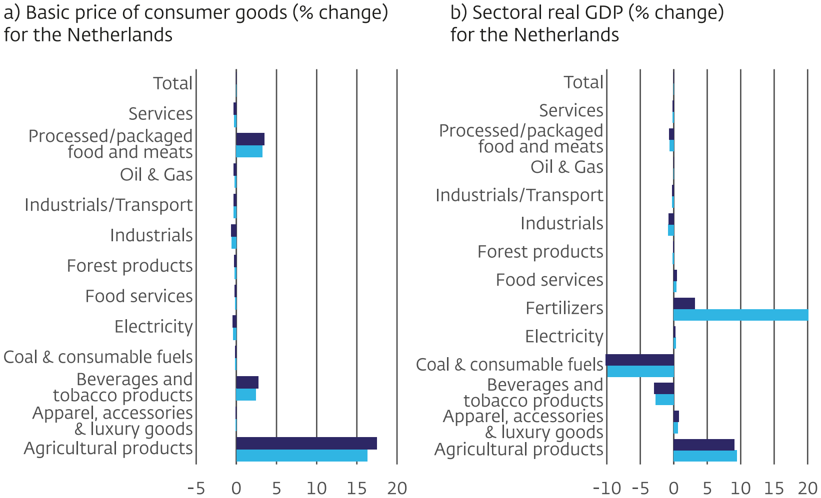
Much of the increase in agricultural output is made possible from the increase in fertilizer use[36]; despite the increase in agricultural production, the prices of agricultural products increase. (Figure 4a, 4b). The output of the fertilizer sector increases in both versions of this scenario, though much more so in case of no additional taxation on fertilizer use. From a pricing perspective, Dutch agricultural products still become more expensive, by more than 15%, but much less so than for countries with a substantial increase in protected areas (e.g. a 129% increase in agricultural product prices in Indonesia in the Half-Earth scenario). Part of this increase is also transmitted to the processed and packaged foods

34. Sanders et. al., 2020
35. This is a result of the scenario choice, which assumes the protection of global areas where biodiversity is the richest.
36. This points to the importance of considering scenarios in conjunction, as probably the increase in fertilizer use could not be possible in light of the current levels of nitrogen pollution in the Netherlands.

and meat sector, which uses agricultural products as input. The price increase in these sectors, combined with the low elasticity of substitution for food, likely lead to a decline in demand and therefore also GDP and prices for other sectors such as services and industrials. On balance, however, the cumulative impact in terms of both GDP and consumer prices is very limited for the Netherlands.

At the world level, agricultural production would decrease by 3.7%. Fertilizer use would increase by 26% in an effort to stimulate agricultural production, further increasing nitrogen emissions. The price of agricultural products would increase by 20%, and that of other food by around 6.7%. The food price increases lower demand for other sectors and lead to lower production and prices in other sectors, muting the aggregate impact.

Figure 4 Initial macroeconomic impact for the Netherlands



Half-Earth protection & Fertilization tax
Half-Earth protection

Source: MAGNET.

To get the full macro-financial scenario that we need in order to estimate losses for financial institutions, we introduce price shocks coming from MAGNET into NiGEM. We map commodity groups between the two models on a best-effort basis (Appendix 1). For the mapped commodities, we impose the MAGNET shock in NiGEM as an exogenous shock that remains constant over time.[37] We then simulate the macroeconomic response in NiGEM.

The limited price shocks produced by the CGE model mean that there is a very limited macro-financial response in this scenario. Specifically, Dutch GDP declines around 0.4% in the first year after the shock produced by the CGE model is introduced in NiGEM for both Half-Earth scenarios, when compared to the baseline. The limited GDP and consumer price effects also mean that the impact on other macro-financial variables is muted. Please refer to section 2.2. for a comparison of economic impacts across all scenarios.

The above results are likely an underestimation of the short-term economic impact of this scenario. The results—sectoral GDP and price impacts—correspond to what would be best thought of as a medium-term equilibrium, given that this estimation is done by a CGE model (see section 4). Therefore, they are unlikely to reflect any potential short-term stress that might result from a less than perfect orderly transition. These 'equilibrium' price impacts are used to estimate the other economy-wide results, meaning that economy-wide results are also likely underestimation of the short-term economic impact.

37. This reflects the fact that the results from MAGNET are equilibrium results, and therefore it seems reasonable that the imposed shocks would result in a permanent shift in the prices of these commodities.

Scenario 2—Pollination decline

A global scenario of a decline in wild pollinators, which decreases the productivity of certain crops. Similar to the Half-Earth protection scenario, the Netherlands as a very competitive economy experiences an increase in its agricultural output to compensate for declines in agricultural output of other economies that are more dependent on pollination for growing their crops. While the economy-wide effect is limited, there is a substantial increase of 38% in the consumer prices of agricultural products in the Netherlands for the 100% pollination decline scenario.

This narrative is inspired by research that suggests that the state of wild pollinators is declining, with negative consequences for agricultural production.[38] Animal pollination is an essential ecosystem service for human well-being.[39] It contributes to the production (yield and quality) of more than three quarters of the leading global food crop types.[40] Most pollinator-dependent sectors are those of fruits (apple, watermelon, grapefruit), nuts & pulses, oil crops sectors (canola, sunflower, rapeseed) and other crop sectors (coffee, cocoa). The main drivers of the current decline of pollinators are land use and configuration, land management, climate change and pesticide use.[41] In addition, managed pollinators cannot fully substitute wild pollinators, as the latter are more effective in crop pollination.[42]

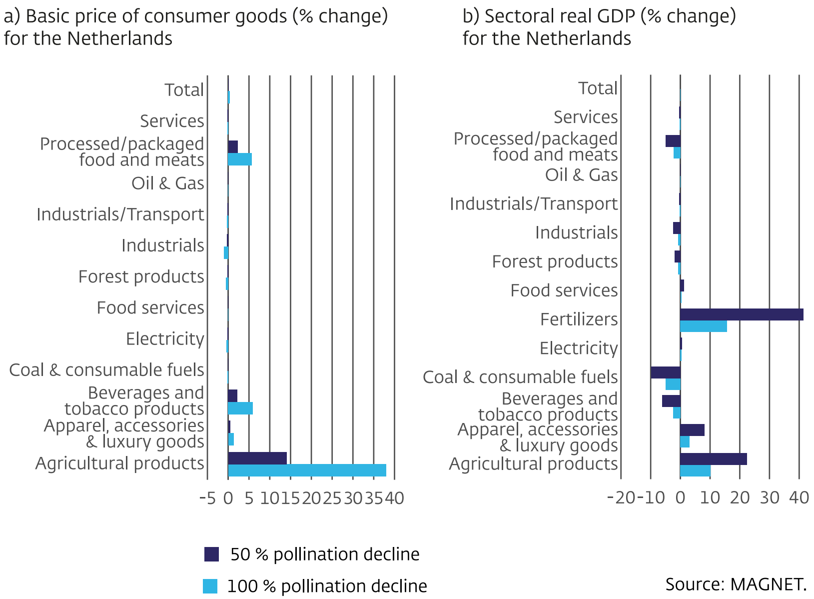
The decline in the population of pollinators is implemented in MAGNET as a productivity shock on the producing sector. In this way, a 10% decline shock means that the affected sector produces

38. Holden, 2006; IPBES, 2016; Tylianakis, 2013; Wagner, 2019
39. Potts et al., 2016
40. IPBES, 2016; Klein et al., 2007
41. Dicks et al., 2021
42. Garibaldi et al., 2013; Tylianakis, 2013

10% less efficiently. The shock on each sector is calibrated using data from Klein et al 2007. This data allows us to calculate a global set of the pollination dependency ratio for the relevant economic sectors included in MAGNET. The maximum dependency is set at 90%. We run two versions of this scenario, under two different assumptions: 100% disappearance of pollinators, or 50% disappearance.

The estimated aggregate macroeconomic impact of even substantial declines in pollination is very limited for the Netherlands and many other developed economies; still, agricultural prices spike by 38% in the Netherlands in case of a 100% decline in wild pollinators. (Figure 5a, 5b) The Netherlands is the country that experiences the largest increase in its agricultural output, by 23%, in case of a full decline of pollination. Similarly as for the Half-Earth protection scenario, the competitive position of Netherlands allows it to substitute the agricultural production of countries that are more dependent on wild pollinators. To satisfy (global) demand, which is inelastic in the case of food, the drop in agricultural productivity resulting from the decline in pollinators is compensated by higher use of other agricultural inputs, such as fertilizer. Despite the increase in fertilizer use, agricultural prices spike by 38% in the Netherlands. This is in line with the increase in agricultural prices in the EU, with Greece experiencing the highest increase (55% compared to the baseline). Still, in the Netherlands, the aggregate shock in consumer prices is limited at +0,4%. Globally, Brazil is most impacted by the spike in total consumer prices. As a big producer and consumer of pollination dependent crops, Brazil experiences an increase of 3.6% in total consumer prices compared to the baseline.

Figure 5 Initial macroeconomic impact for the Netherlands



Source: MAGNET.

Introducing the price shocks we get from MAGNET into NiGEM, we get a muted macro-financial response for the scenario of 50% decline in pollination. Specifically, Dutch GDP declines around 0.2% compared to the baseline. The limited GDP and consumer price effects also mean that the impact on other macro-financial variables is muted. Please refer to section 2.2. for a comparison of economic impacts across all scenarios.

The above results are likely an underestimation of the short-term economic impact of this scenario. The results—sectoral GDP and price impacts—correspond to what would be best thought of as a medium-term equilibrium, given that this estimation is done by a CGE model (see section 4). Therefore, they are unlikely to reflect any potential short-term stress that might result from a less than perfectly orderly transition. These 'equilibrium' price impacts are used to estimate the other economy-wide results, meaning that economy-wide results are also likely underestimation of the short-term economic impact.

Scenario 3—Taxation of EU imports associated with a high risk of deforestation

An EU scenario aimed at disincentivizing the import into the EU of products with a high deforestation footprint. The products are taxed in such a way that their price doubles. While the macroeconomic impact of the scenario is muted for the Netherlands, it does highlight the important role that models' substitution parameters have: the economic impact is almost null when standard Armington elasticities are used, while the impact is more pronounced when these elasticities are lowered.

The narrative is inspired by the EU proposal for Regulation on deforestation free supply chains, put forward by the EU Green Deal and included in the priorities set out in the Biodiversity strategy for 2030 and the Farm to Fork Strategy.[43] The regulation is aimed at minimizing the risk of deforestation associated with products that are imported into the EU or exported by the EU. The provisional agreement sets mandatory due diligence rules for the actors involved in trade commodities such as palm oil, beef, timber, coffee, cocoa, rubber, and soy, as well as a number of derived products such as chocolate, furniture, printed paper, and selected palm oil based derivatives.

43. REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the making available on the Union market as well as export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing Regulation (EU) No 995/2010

Deforestation is a major driver of habitat loss and disturbance in biodiversity hotspots[44], with negative consequences for biodiversity[45]. Deforestation is also a major driver of greenhouse gas emissions contributing to climate change.[46] Consumption patterns and associated production structures in the EU are driving deforestation in tropical and sub-tropical countries.[47]

The shock is implemented in MAGNET as an increase of ad valorem import tax rate by +100%, applied to a set of commodities imported into the EU that are associated with a high risk of deforestation. [48] In order to grasp the extent to which the elasticities of the model drive results, we run this scenario in two versions.[49] One version utilizes the 'normal' substitutability parameters—Armington elasticities[50]—of the model when it comes to substitution between the taxed commodities and those imported from other regions. Another version utilizes lower Armington elasticities, to try to simulate the limited substitution that is more typical of a shorter-term reaction.

The macroeconomic impact for the Netherlands and EU at large hinges on whether the taxed imports are easily substitutable. (Figure 6a, 6b) In the scenario where the taxed imports can be easily

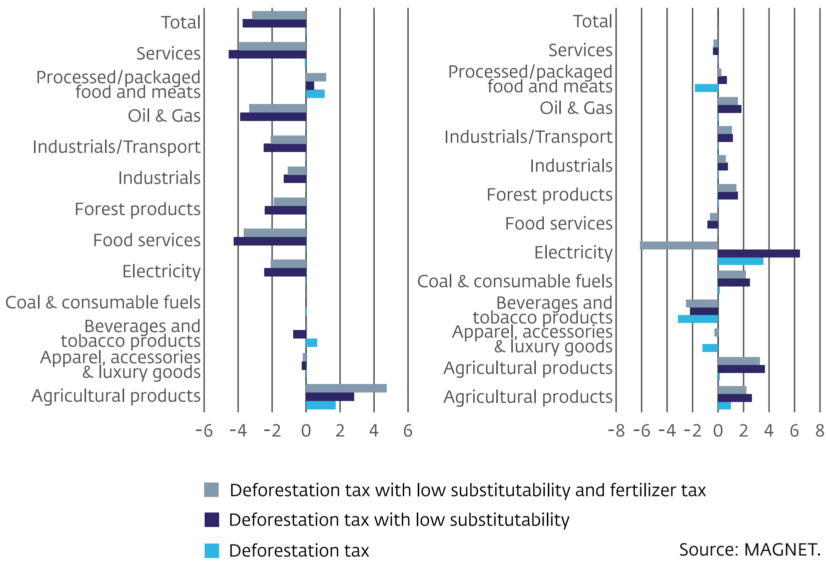
44. Barlow et al., 2016; Pereira et al., 2012
45. Alroy, 2017; Giam, 2017; Gibson et al., 2011; Tracewski et al., 2016
46. Baccini et al., 2017; Gatti et al., 2021; IPCC, 2019
47. Hoang & Kanemoto, 2021; Pendrill et al., 2019
48. The full list of taxed commodities is: Soy and derived products (oilcake, vegetable oils) from Argentina and Brazil; Forest products from Brazil; Cattle meat products from Brazil; Grains from Brazil; Cocoa from cocoa producing region in Africa; Palm oil and derived products (oilcake, vegetable oils) from Indonesia and Malaysia; Rubber from Indonesia and Malaysia.
49. Such an exercise of amending elasticities could also be useful for other scenarios run through MAGNET, given that the medium to long-term nature of the estimations of CGE models could be considered too 'optimistic' when reflecting challenges of substituting inputs in the short-term. However, it is challenging to find a sound basis for re-calibrating these elasticities.
50. Armington substitution elasticities regulate the substitution possibility between domestic and imported goods, and within imported goods they regulate substitution between different importing countries for a given commodity.

substituted by imports from other regions, the economic impact in the Netherlands is muted. This is largely due to the limited categories of products taxed. However, in the scenario where substitution is more limited—Armington elasticities are decreased—economic impact is more pronounced. The scenario with the modified Armington elasticities is intended to highlight the important role that the elasticities used by the model have in driving the results, rather than the magnitude of the results. The results are likely not reliable, as these elasticities are artificially and uniformly lowered across the board, without considering product and country specifics.

Figure 6 Initial macroeconomic impact for the Netherlands

a) Basic price of consumer goods (% change) for the Netherlands

b) Sectoral real GDP (% change) for the Netherlands



Source: MAGNET.

Introducing the price shocks we get from MAGNET into NiGEM, we do not get any significant macro-financial response. This scenario has the lowest impact from those considered. Please refer to section 2.2. for a comparison of economic impacts across all scenarios.

The above results are likely an underestimation of the short-term economic impact of this scenario. The results—sectoral GDP and price impacts—correspond to what would be best thought of as a medium-term equilibrium, given that this estimation is done by a CGE model (see section 4). Therefore, they are unlikely to reflect any potential short-term stress that might result from a less than perfectly orderly transition. These 'equilibrium' price impacts are used to estimate the other economy-wide results, meaning that economy-wide results are also likely an underestimation of the short-term economic impact.

Scenario 4—Ending harmful subsidies

The main version of this scenario is a global tail scenario in which fossil fuel subsidies are eliminated.[51] To understand cross-sectoral dynamics, we create a second version of the scenario where both fossil fuel subsidies and harmful agricultural subsidies are eliminated for the EU-27. The global scenario of phasing out explicit fossil fuel subsidies leads to a very limited peak impact of 0.3% GDP decline compared to the baseline. The global scenario of ending all (both implicit and explicit) fossil fuel subsidies leads to a peak GDP decline of 3% within 2 years compared to the baseline. The European cross-sectoral analysis shows that the price impact of a phase out of all subsidies is substantial for fuel intensive sectors like transport, basic metals and chemicals; the effect of the phase out of only explicit subsidies is much smaller.

51. In this study we follow the IMF definition of fossil fuel subsidies, which is different from the definitions used in the Dutch Budget Memorandum.

The narrative is inspired by Target 18 of the Kunming-Montreal Global Biodiversity Framework, agreed in December 2022. Target 18 advocates phasing out subsidies harmful to biodiversity by at least USD 500 bn per year.[52] At the EU level, phasing out environmentally harmful subsidies will be essential to achieve the objectives of EU's 8th Environment Action Programme[53], which builds on the European Green Deal[54].

Climate change is the second biggest driver of biodiversity loss, with its importance set to increase if global warming is not addressed.[55] Fossil fuel consumption is the main cause of climate change, and subsidies further encourage the usage of fossil fuels. Therefore, fossil fuel subsidies fall squarely under the category of subsidies that harm biodiversity, as do some of the subsidies directed to agriculture and fisheries.[56,57] Environmentally harmful subsidies (EHS) can be defined as a government action that confers an advantage to consumers or producers, in order to supplement their income or lower their costs, but in doing so, discriminates against sound environmental practices.[58]

We run two versions of this scenario- a global and a European one. The global scenario consists in immediately eliminating all fossil fuel subsidies at a global level. Due to data limitations, this scenario does not allow for a cross-sectoral analysis. To gain cross-sectoral insights, the European scenario focuses on EU-27 countries.

52. CBD, 2022
53. EU, 2022
54. EC, 2019
55. IPBES, 2019
56. Also see OECD study 3e9118d3-en.pdf (oecd-ilibrary.org
57. Given the limited magnitude of subsidies going to fisheries, they are excluded from the analysis. In 2018, global fisheries subsidies were estimated to be USD 35.4 billion, of which capacity-enhancing subsidies were USD 22.2 billion. The top five subsidising political entities (China, European Union, USA, Republic of Korea and Japan) contributed 58% (USD 20.5 billion) of the total estimated subsidy (Sumaila et al., 2019)
58. CBD, 2018

In this scenario, we immediately stop all European fossil fuel related subsidies and a share of agricultural subsidies that is considered harmful.

The IMF[59] decomposes fossil fuel subsidies into two types: explicit and implicit subsidies. When the retail price is below a fuel's supply cost, the difference is defined as an explicit subsidy. For a non-tradable product, supply costs consist of production costs, distribution costs and margins. For internationally tradable products, the supply costs equal the opportunity cost of consuming the product domestically, instead of selling it abroad. Explicit subsidies also include direct support to producers. Implicit subsidies occur when the retail price fails to include all external costs. Examples of external costs are greenhouse gas emissions and damages to biodiversity. In both scenarios—Global and European, we distinguish between a phase out of explicit fossil fuel subsidies and total (explicit and implicit) fossil fuel subsidies.

59. IMF, 2023

Box 1 What counts as a fossil fuel subsidy?

Definitions of fossil fuel subsidies differ. The recent 2024 Budget Memorandum[60] included a chapter on fossil fuel subsidies and estimated that the total size of these subsidies was between €39.7 and €46.4 billion for 2023. According to the Budget Memorandum, fossil fuel subsidies in The Netherlands mainly consist of foregone tax revenues. The difference in excise duties on electricity and gas between small and large consumers would be seen as a fossil fuel subsidy according to this definition. The IMF definition differs, as it looks either at explicit fossil fuel subsidies—which do not include lower tax rates—or implicit fossil fuel subsidies—which are defined as a pricing deficit of external effects. To the extent that the degressive energy tax structure lowers the tax level paid by large consumers below the optimal price (i.e. increases the pricing deficit), this is included in the IMF definition of implicit subsidies (but the difference between the consumer retail price is not relevant). According to the IMF definition, the sum of explicit and implicit fossil fuel subsidies in the Netherlands amounts to €15.9 billion in 2019.

We use the IMF definition for theoretical reasons and international comparability. The subsidy definition of the Budget Memorandum is partly a result of the benchmark values used. For instance, a country that implements higher excise duties on gas for consumers than for manufacturers provides fossil fuel subsidies according to the Budget Memorandum definition. This is also true when both groups are taxed at a high level. The IMF definition checks whether

60. Ministerie van Financiën, 2023

all external effects are incorporated in the retail price and is therefore more consistent. Moreover, the IMF provides data for the majority of countries, which allows us to run international scenarios. PBL and CPB (2023)[61] use an approach to estimate fossil fuel subsidies that closely resembles the IMF definition of fossil fuel subsidies.

PBL and CPB assess whether the external effects of carbon emissions are fully priced in. The pricing deficit that remains, is defined as a fossil fuel subsidy. Based on this approach PBL and CPB report a pricing deficit of €35.2 billion for 2021. The substantial difference with the IMF number can be explained by several methodological differences. Most importantly, PBL and CPB use a higher benchmark carbon price of €130 per tonne of CO_2 (IMF uses $60 per tonne) and also take into account the pricing deficit of bunkering fuels by international air and maritime transportation.

For agricultural subsidies, included only in the European scenario[62], we assume that 70% of the Common Agricultural Policy (CAP) pillar 1 subsidies are harmful. Pillar 1 consists of direct income support (per hectare) and market measures (price support). These subsidies tend to stimulate agricultural production, which is in general considered as one of the main drivers of biodiversity loss.[63,64] However, since EU countries have to allocate 30% of the income support to greening[65], we define only the remaining 70% of pillar 1

61. PBL & CPB, 2023
62. This is due to data constraints and complexities of the agricultural subsidies at the global level.
63. European Environment Agency, 2019
64. European court of Auditors, 2020
65. European Parliament, 2023

subsidies as harmful. Arguably, the 70% is a conservative estimate, as greening requirements are considered 'undemanding' and the positive impact of greening payments on farmland biodiversity 'cannot be clearly demonstrated', according to the European Court of Auditors.[66,67] For this analysis, subsidy data of 2019 is used.

For the global scenario, the implementation of ending harmful subsidies is done in NiGEM. We use a standardized simulation in NiGEM to obtain first indicative estimates of the macroeconomic effect of ending a) explicit fossil fuel subsidies and b) all fossil fuel subsidies. Our shock uses IMF country-level data on fossil fuel subsidies and GDP for 2019. To operationalize the shock we first map the IMF country data (191 countries) into 54 NiGEM countries and regions. The simulation is an exogenous shock to individual country fossil fuel prices, allowing for world pre-tax price of fossil fuels to respond endogenously. The simulation is run in forward mode allowing for monetary authorities to respond and assuming fiscal solvency is on. No offsetting fiscal stimulus equal to the amount of the phased out subsidies is assumed.

For the EU-27 scenario, given the availability of sectoral data, the implementation of ending harmful subsidies is done using an input-output (I-O) model. In the I-O model, it is possible to estimate sectoral price effects, which allows us to analyze sectoral heterogeneity. Since we do not have data on the sectoral allocation of fossil fuel subsidies, we assume that the subsidies are allocated proportionally to fossil fuel consumption shares per fossil fuel type. For most EU countries, Eurostat provides detailed sectoral data for

66. European court of Auditors, 2020
67. We did not conduct an in-depth analysis on the harmful effects of CAP pillar 1 subsidies. Therefore, the 70% proportion used in this analyses is an assumption.

the manufacturing sectors on fossil fuel consumption per fossil fuel type.[68]

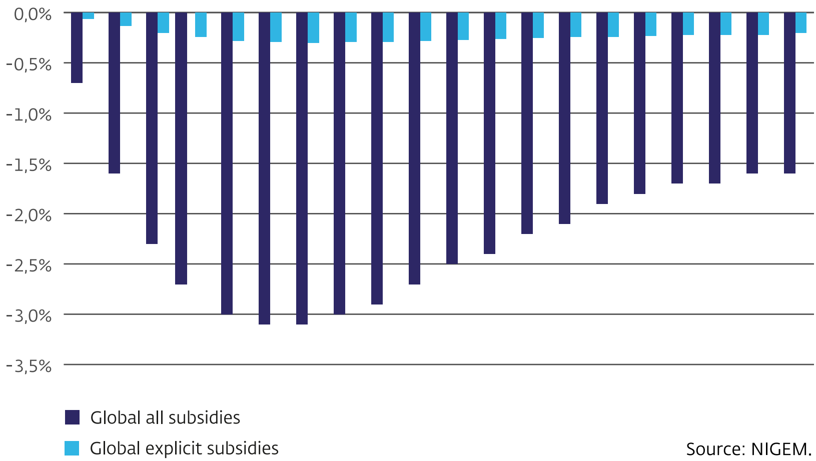
Results for the global scenario of ending fossil fuel subsidies

The ending of all fossil fuel subsidies implies a short-run negative GDP effect for the Netherlands. This negative effect shrinks over time because the scale of subsidies in the Netherlands is small relative to the world average.[69] We estimate two global scenarios in NiGEM using the IMF fossil fuel subsidy database. An exogenous shock is introduced to gas, oil and coal fossil fuel prices in 54 different countries or regions such that 1) explicit subsidies and 2) all subsidies, both explicit and implicit, are eliminated. The impact of eliminating all subsidies initially leads to a general increase in the domestic cost of fossil fuel energy sources and an increase in the inflation rate. Equity markets decline, world trade is lower and the unemployment rate increases. The initial negative effect on NL GDP is strong, peaking at a level difference of 3 percentage points of GDP in year 2 compared to baseline. Over time firms reduce the energy intensity of their production processes, and within the energy mix they substitute away from fossil energy towards renewable energy. These adjustments will gradually help to mitigate the initial cost increase. Note however that the estimated level of all fossil fuel subsidies is lower in NL (1.9% of GDP in 2019)[70] than worldwide (7.4% of GDP). This means that over time this negative GDP impact starts to dissipate as the NL economy begins to benefit from this relative competitive advantage. Over a 4-year horizon, the ending of all fossil

68. Unfortunately, detailed data is incomplete/missing for Spain, Italy, Ireland, Greece, Luxembourg and Sweden. Fossil fuel subsides to the manufacturing sector in these countries are allocated to more detailed sectors proportional to their respective value added shares.
69. In a situation where The Netherlands would decide to phase out fossil fuels unilaterally, such a competition effect would not exist and therefore the negative GDP effect would be more persistent.
70. This figure is lower than in the Budget Memorandum 2024 and CPB & PBL (2023) due to methodological differences outlined in Box 1.

fuel subsidies leads to a 1.8 percentage point decline in GDP in the Netherlands. In the case of only explicit subsidies the impact is small, peaking at 0.3% fall in GDP in year 2.

Figure 7 NL GDP % deviation from baseline



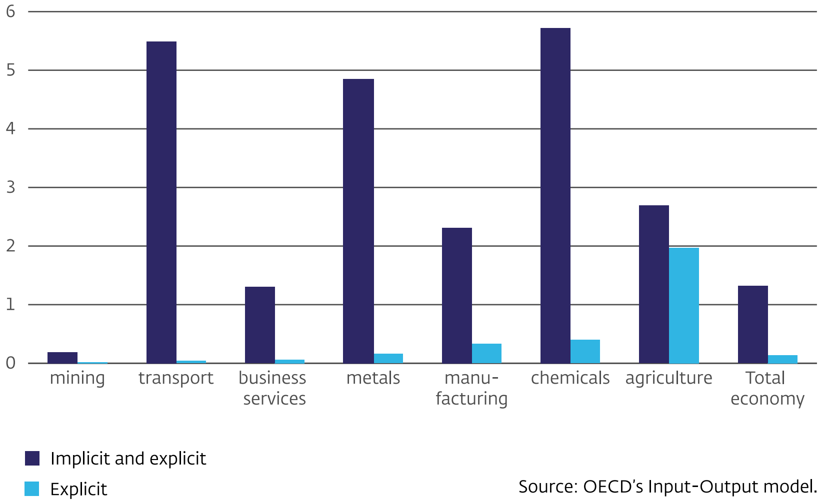
Source: NIGEM.

Results for the EU-27 scenario of ending both fossil fuel and harmful agricultural subsidies

The EU-27 scenario differs in several respects from the global scenario, making the results of these two scenarios not directly comparable. This scenario only focuses on cross-sectoral price and sales impacts. Given that it assumes that fossil fuels are only phased out in the EU-27, it may lower the impact of the shock through trade linkages. In addition, the absence of substitution effects in the I-O model also implies that there is no competitive advantage due to a smaller price increase for countries that relied less heavily on harmful subsidies.[71] Therefore, these results are not directly comparable to those of the global scenario.

The effect of ending fossil fuel subsidies and agricultural subsidies in the EU-27 is strongly heterogeneous across sectors. Figure 8 shows that the price impact of a phase out of explicit and implicit harmful subsidies is substantial for fuel intensive sectors like transport, basic metals and chemicals[72]. However, the effect of the phase out of explicit subsidies is smaller. The difference can be explained by the relatively low level of explicit fossil fuel subsidies in The Netherlands, apart from the agricultural subsidies. The amount of implicit subsidies is higher, due to the fact that negative

Figure 8 Change in NL consumer prices due to harmful subsidy phase out (%)



Source: OECD's Input-Output model.

71. The harmful agricultural subsidies included in this scenario are treated as explicit subsidies.
72. It is assumed that producers will pass through 100% of the cost increase, which corresponds to a situation of perfect competition.

externalities are not fully priced-in. This is, amongst others, caused by insufficient carbon pricing in The Netherlands.

The change in consumer prices subsequently affects the level of sales of Dutch producers. Since the phase out of explicit harmful subsidies only has a significant price effect for the agricultural sector, the demand response is expected to be muted for most sectors. In contrast, the negative sales effects of a phase out of implicit and explicit subsidies are substantial for several sectors, reflecting the larger consumer price effects. For instance, sales in the metals sector may decrease by up to 7-18%.

Scenario 5—Nitrogen measures

Two Dutch scenarios in which i. government measures to reduce nitrogen pollution have a direct impact on agriculture, or ii. a lack of the former measures limits construction.[73] *The scenario with no agricultural measures has a comparatively larger economic impact than the scenario with an initial shock in the agricultural sector, with a 1.2% and 0.65% GDP decline respectively when compared to the baseline in year 3. The difference in impact is explained by the larger share of construction in Dutch GDP, and the larger sectoral spillovers of a decline in construction.*

Excessive nitrogen depositions have a negative effect on biodiversity and nature quality. In most Dutch Natura 2000 areas, the maximum nitrogen deposition allowed under the EU Habitats Directive is being exceeded, which implies that nitrogen emissions must be reduced. Only 12% of Dutch Natura 2000 areas are in good shape and The Netherlands ranks lowest in Europe regarding

73. Other countries (like Belgium and Germany) also have to take measures to reduce nitrogen emissions, but the nitrogen problem is particularly relevant in the Netherlands because the latter emits much more nitrogen and has much more livestock per hectare than other countries. See Rijksoverheid (2023)

biodiversity[74]. Agriculture is the biggest contributor, responsible for 46% of total nitrogen emissions in 2019.[75] Other sectors responsible for nitrogen emissions are transportation, construction and industry.

To reduce nitrogen emissions, the government has enacted a scheme to buy out some of the farmers whose activities emit nitrogen emissions so that they can shut down, relocate or switch to different activities. To meet the nitrogen reduction targets, total agricultural production will need to be reduced by an estimated 9%[76]. This reduction will also affect suppliers to the agricultural sector. Given the voluntary nature of the scheme, it seems unlikely that nitrogen emission reduction targets will be reached by this measure alone.

Other economic activities, especially construction, could also be impacted given their nitrogen emissions, especially when nitrogen reduction in agriculture is insufficient. For example, the cancellation of the 'Bouwvrijstelling'[77] in November 2022 could potentially limit production in the construction sector. In residential construction, an estimated 91% of housebuilding projects can continue without additional measures, because their nitrogen deposition is very small[78]. Of the remaining 9% of housebuilding projects, around a third of projects will almost certainly have to be cancelled and two thirds have a chance of continuing subject to additional measures (such as an ecological report and more usage of electric machinery and vehicles). This causes delays and higher costs, meaning that part of these projects could also be cancelled. This study explores a scenario in which a third of the housebuilding

74. PBL, 2020
75. Milieudefensie (2023)
76. CPB, 2023
77. The 'Bouwvrijstelling' meant that no permit was needed for temporary nitrogen emissions during construction.
78. Koning & Endhoven, 2023

projects that might be able to go through with additional measures will be cancelled, which is 2% of total projects. When added to 3% that will almost certainly be cancelled, this results in a decrease of 5% in residential construction. Non-residential construction consists mostly of infrastructure projects, which are often more affected by nitrogen rules than residential construction (CPB, 2023). This is because infrastructural projects are usually tied to a specific location and therefore not flexible to change location when they are close to a Natura 2000 area. Furthermore, these are usually larger projects that emit more nitrogen.[79] Therefore, this scenario assumes that the cancellation rate is twice as high in infrastructural projects as in residential construction, resulting in a 10% decrease in non-residential construction. This brings the decline in the total construction sector to 5.7%.[80]

Using the above projections, we construct the *Nitrogen agricultural measures* scenario using an initial shock of 9% decrease in agricultural output and the *Nitrogen no agricultural measures* scenario using an initial shock of a 5.7% decrease in construction output. The former scenario assumes agricultural production is reduced sufficiently in response to nitrogen pollution. The latter scenario occurs if there is insufficient action to limit agriculture, which could potentially lead to a decrease in construction activity.

The economy-wide impact of the two assumed shocks is first estimated using an Input-Output database, and then using its output in DNB's semi-structural macroeconomic model DELFI.

79. The Ministry of Finance expects underinvestment in infrastructure to reach an estimated €3.5 billion by 2027, partly due to the restrictions surrounding nitrogen. See Government Budget 2023
80. This is a worst case scenario. Recent research suggests that the nitrogen rules and the Bouwvrijstelling have had no or a very limited effect on building permits in the period 2019-2021, partly due to an increase in construction projects in other regions. See Rouwendal (2023)

The spillover impact of the shocks in agriculture and construction on other economic sectors is calculated using the OECD's global Input-Output model.[81] These effects are then used as input in our macro-economic model DELFI, to produce a more comprehensive macro-financial scenario needed to estimate financial losses.

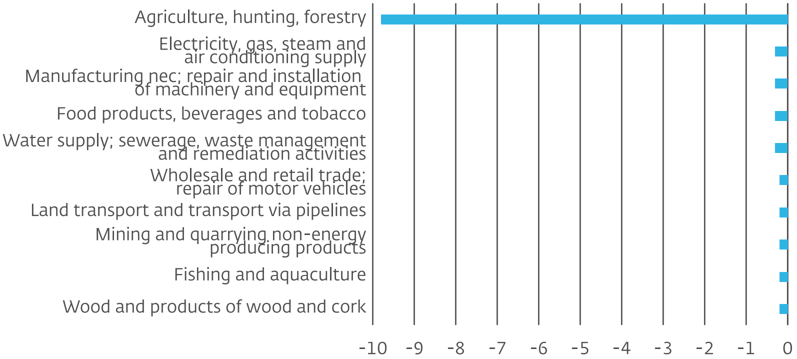
The immediate impact of the *nitrogen agricultural measures* scenario is a decline in Dutch GDP of 0.5%, while the immediate impact of the *nitrogen no agricultural measures* scenario is a decline in Dutch GDP of 1.1%. If nitrogen targets are met by reducing agricultural production by 9%, this will impact the total economy by 0.5% of GDP. However, if insufficient action is taken and construction is limited by 5.7%, this will likely have a larger negative impact on the economy of 1.1% GDP. While agriculture is the largest emitter of nitrogen, the impact of this scenario is smaller than that of the construction scenario given that the added value in this sector only makes up 1.5% of Dutch GDP. Construction, however, makes up 4.9% of the Dutch economy.

Spillover effects across sectors are strong. The sectors that experience the strongest indirect impacts are those that produce important inputs for the construction sector, namely production of non-metallic mineral products (-3.5%), wood (-2.1%), mining and quarrying (-1.8%) and fabricated metal production (-1.6%). The drop in agricultural production has a much smaller negative impact on other sectors, with a maximum of 0.3%. These are primarily sectors that produce inputs for agriculture, such as electricity & gas, machinery repair and water supply. Some downstream sectors are however also impacted, e.g. food production declines by 0.3%. The spillovers in

81. This model includes quantitative data on intermediate flows and final demand for 36 industries in 56 countries, including the EU27 and its main trading partners.

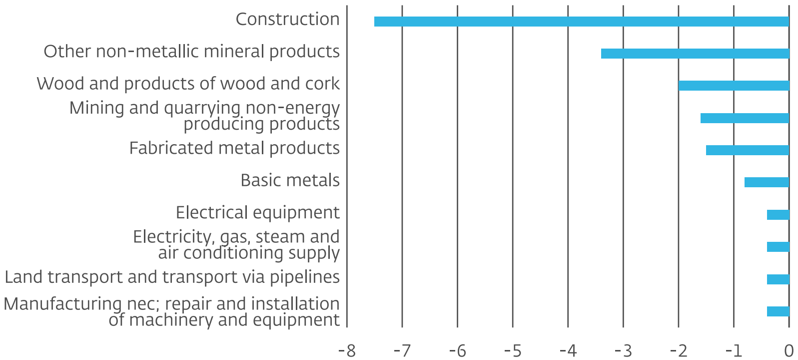
terms of GDP loss to other EU countries are negligible, namely 0.1% for Luxembourg and Belgium and even less for the rest of the EU.

Figure 9 Estimated effects of a value added drop of 9% in agriculture, through the I-O model (nitrogen agricultural measures scenario)



Source: OECD's Input-Output model.
Note: The total effect on the agricultural sector is larger than the initial shock of 9% because the negative effect on other sectors also negatively affects the agricultural sector.

Figure 10 Estimated effects of a value added drop of 5.7% in construction, through an I-O model (nitrogen no agricultural measures scenario)



Source: OECD's Input-Output model.
Note: The total effect on the construction sector is larger than the initial shock of 5.7% because the negative effect on other sectors also negatively affects the construction sector.

DELFI does not distinguish between different economic sectors. To translate the scenario into DELFI, it is assumed that the share of exports corresponding to agricultural exports is permanently lower so that GDP drops by 0.5% in year 1 in line with the I-O estimations. The remainder part of exports is allowed to freely respond to changes in domestic costs and export prices. To simulate the drop in construction value added in the scenario where insufficient action is taken to reduce nitrogen emissions, government investments are assumed to be permanently lower so that the drop in GDP in year 1 equals 1,1% in line with the I-O estimations. By attributing the shock completely to government investment, both business investment and residential investment are allowed to react endogenously to the fall in GDP.

Reducing agricultural production sufficiently to tackle the nitrogen problem leads to a maximum cumulative GDP loss of 0.7% GDP by year 3. By year 4 unemployment has increased by 0.7% in this scenario (Table 2). The increase in unemployment is related to the assumption of unchanged productivity in year 1, so that labor hoarding is assumed to be absent. The more adverse economic situation reduces demand which results in a cumulatively lower HICP (harmonized index of consumer prices) inflation of 0.5% in year 4. House prices also decrease as a result of lower demand, leading to a drop in house prices of 0.7% in year 4. Interest rates and exchange rates are assumed to be constant.

Table 1 Nitrogen agricultural measures scenario

Percentage points deviation from baseline

Year	1	2	3	4
GDP	-0,50	-0,64	-0,65	-0,58
Unemployment rate	0,42	0,61	0,67	0,66
HICP	0,00	-0,09	-0,32	-0,54
House prices	-0,06	-0,19	-0,36	-0,66

Source: DELFI.

Not taking sufficient action to reduce the nitrogen emissions of the agricultural sector might result in a worse economic outcome, where GDP is 1.2% lower in year 3. The economic damage in terms of GDP due to the potential impact on the construction sector is significantly larger than when action is taken to reduce nitrogen emissions in agriculture. In the nitrogen no agricultural measures scenario house prices drop by 1.2% cumulatively in year 4, due to the worsening economic conditions. The decrease in the number of new houses built, which is associated with the lower added value of construction, is assumed to have a negligible effect on house prices given that it has an insignificant effect on the total number of houses. HICP also drops due to the worsening economic conditions, resulting in a lower cumulative price level of 1.2% in year 4. The increase in unemployment reflects the sharper drop in GDP compared to the nitrogen scenario with agricultural measures, in particular in the first years of the scenario.

Table 2 Nitrogen no agricultural measures scenario

Percentage points deviation from baseline

Year	1	2	3	4
GDP	-1,11	-1,36	-1,24	-1,03
Unemployment rate	0,95	1,20	1,03	0,68
HICP	0,01	-0,26	-0,81	-1,22
House prices	-0,13	-0,40	-0,68	-1,18

Source: DELFI.

2.2 Summary of macroeconomic impacts

As a developed and competitive economy in which agriculture makes up 1.55% of GDP as of 2021, the Netherlands only experiences a limited economic impact due to scenarios that primarily affect agriculture.[82] (Figure 11) These scenarios do, however, produce strong heterogeneous impacts across economic sectors, with agricultural prices substantially increasing in several instances. As also mentioned in section 2.1, for the scenarios *Half-Earth protection*, *Taxation of EU imports associated with high deforestation risk*, and *Pollination decline*,—for which the economic impacts are the smallest—the short-term stresses are probably underestimated due to modelling limitations.

Our results show that the Dutch economy is more severely impacted by scenarios that (also) directly impact the non-agricultural sectors. (Figure 11) Such are the *Nitrogen no agricultural measures scenario* and the global *Ending total harmful subsidies* scenario. The impact of the *Ending total harmful subsidies* scenario materializes

82. The macroeconomic outcomes presented in Figures 11 to 14 are the output of the DELFI model for the nitrogen scenarios and the output of the NiGEM model for the rest of the scenarios.

in sectors that are heavily dependent on fossil fuel subsidies. While the impact of phasing out explicit harmful subsidies is limited given the small magnitude of such subsidies, phasing out total harmful subsidies on a global scale produces a 3% GDP shock compared to the baseline in the second year of the forecast. The impact of the *Nitrogen no agricultural measures scenario* is, at its peak, a 1.4% GDP shock compared to the baseline. The most affected sector in this scenario is (assumed to be) the construction sector, whose spillover effects also materialize in other sectors such as mineral and wood products. For these two more impactful scenarios, we estimate the degree of financial losses in section 3.

The relative magnitude of the GDP impacts across the scenarios is also mirrored in the relative impact on unemployment. (Figure 12) Only the global scenario of ending total harmful subsidies produces a significant impact on interest rates and equity prices. (Figure 13, 14) Specifically, the global scenario of ending total harmful subsidies has the largest impact on unemployment, at a peak of around 3% in the second year after the initial shock compared to the baseline. The Dutch nitrogen scenario with no agricultural measures has the second largest impact—1.2% peak unemployment in year 2 compared to the baseline—and the Dutch nitrogen scenario with agricultural measures has the third largest impact 0.7% peak unemployment in year 3 compared to the baseline. When it comes to macro-financial impact, only the global scenario of ending total harmful subsidies has a meaningful impact on interest rates and equity prices.[83]

83. For the nitrogen scenario, the long term rate is assumed not to change compared to the baseline given the size of the shock and the implied minimal response of government debt, which makes a change in the Dutch spread implausible. Similarly, the Dutch equity index is also assumed not to change compared to the baseline, given the limited weight of the construction sector in the overall index, and the fact that in the model both a Dutch and the world MSCI index is used, with the latter not changing.

Figure 11 NL GDP impact of each scenario

NL GDP (difference to base in %)

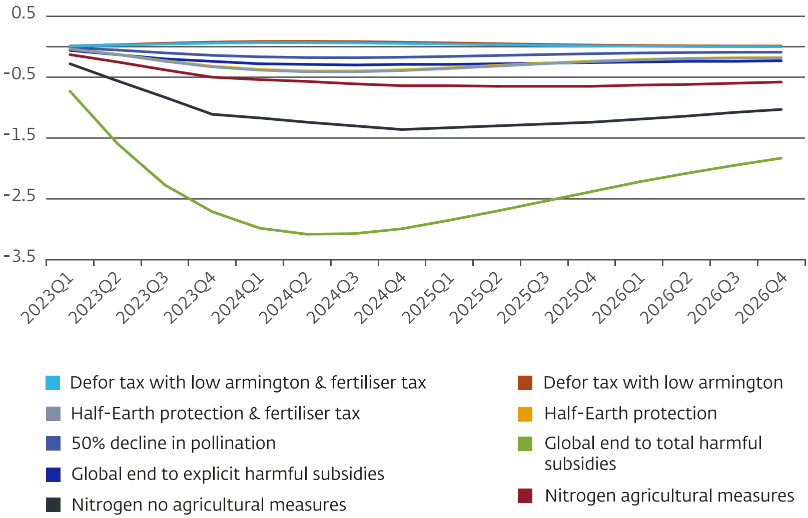


Figure 12 NL unemployment impact of each scenario

NL Unemployment (Difference to base in % point)

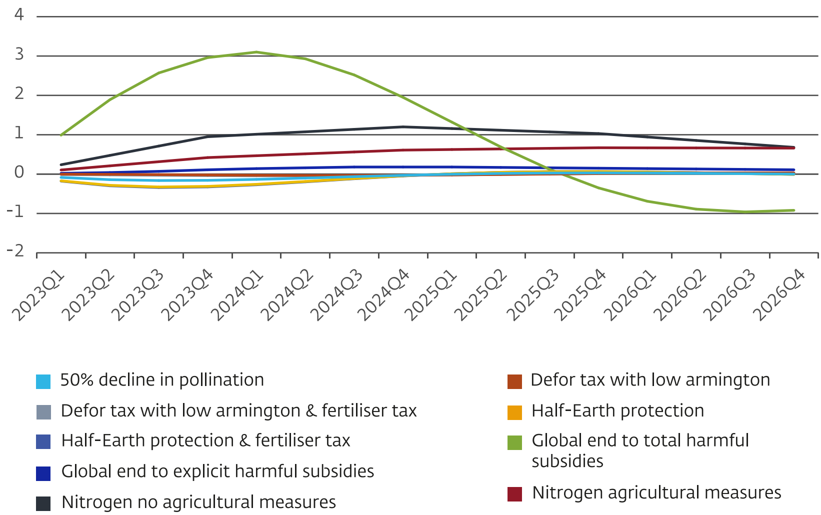


Figure 13 NL interest rate impact of each scenario

NL nominal Long-term rate (difference to base in%)

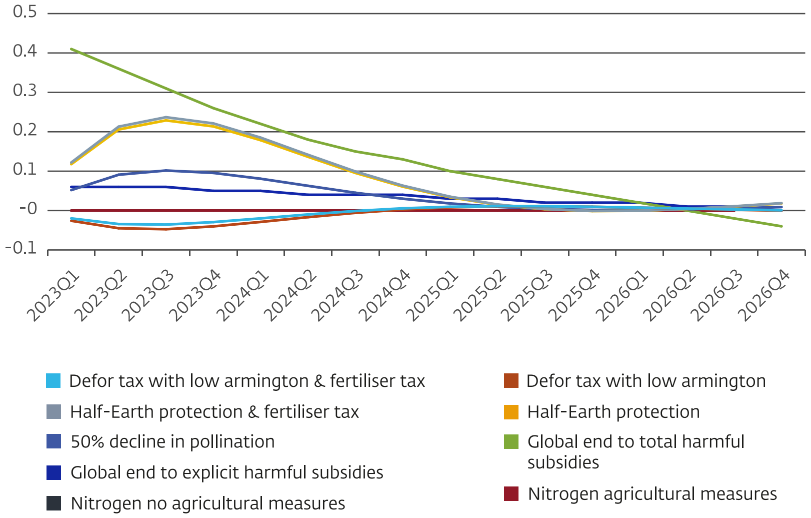
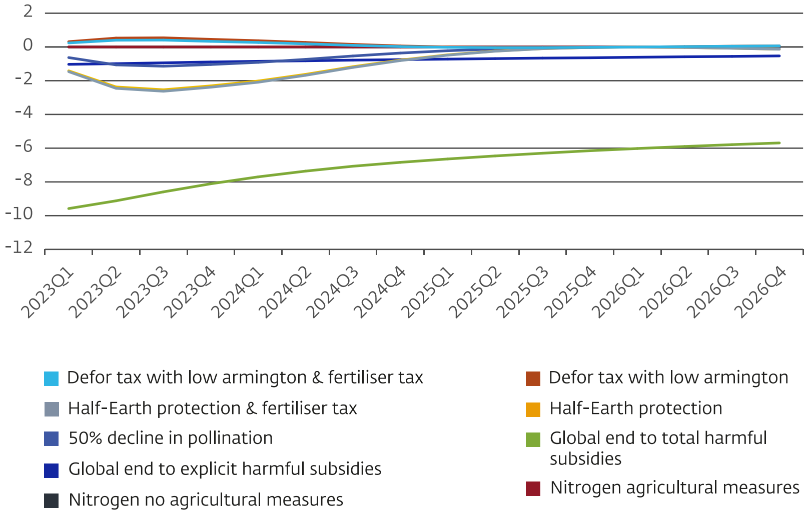


Figure 14 NL equity index impact of each scenario

NL Equity price index (difference to base in %)



3 Financial impact

The financial impacts under each scenario are calculated using available data on financial institutions' exposures. We focus on the most material risk aspects. For banks, we study implications for credit risk using supervisory data on bank loans. For insurers and pension funds, we focus on market risk implications using exposure data for the institutions that are subject to Solvency 2 and FTK reporting in the Netherlands.

3.1 Financial institutions' exposures

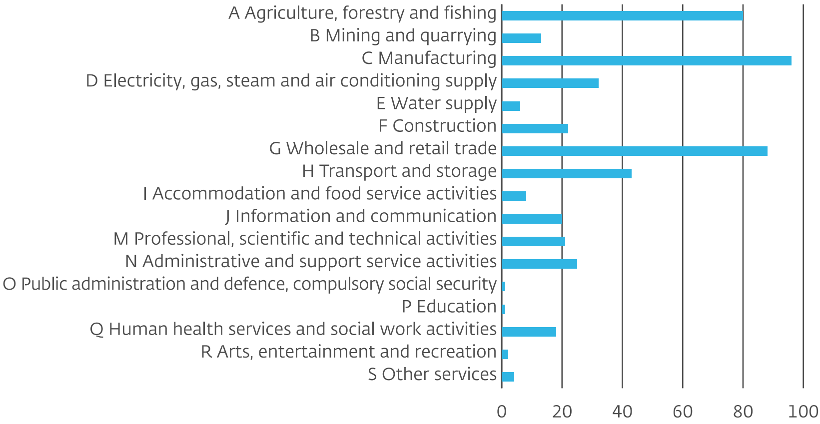
The sectoral heterogeneity of the economic impacts of nature scenarios points to a possible need to also consider this heterogeneity when estimating an impact on financial institutions. Two relevant aspects in this regard would be i. the potentially different impact on financial institutions given entity-specific sectoral breakdowns of exposures and ii. potential contagion effects if many financial institutions have concentrated exposures on particular sectors. The sectoral nature of macroeconomic impacts is outlined in section 2.1[84]. For calculating the impact on financial institutions, however, this study uses economy-wide impacts as an intermediate step, not taking into account sectoral heterogeneity

84. The definition of sectors is different in section 3.1 compared to section 4.1, as the former is based on the MAGNET model and the latter is based on sectoral NACE codes.

(see also section 4). It is still informative, however, to observe the extent to which Dutch financial institutions are exposed to different economic sectors at an aggregated level (Figure 15, 16). For future more detailed analyses on sectoral financial impacts, sectoral heterogeneity across entities' portfolios would also be relevant.

Figure 15 Sectoral breakdown of banks' loans to NFCs (EUR bn)

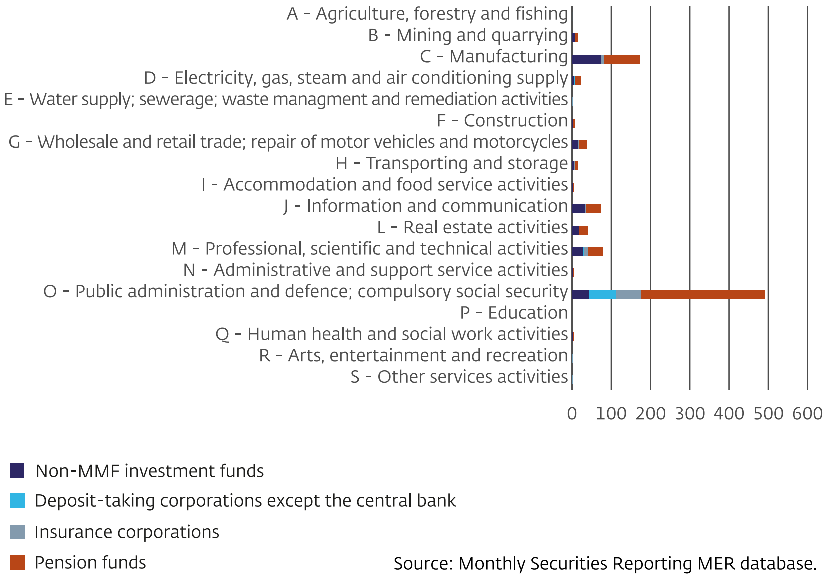
Exposures in EUR bn



Source: FINREP.

Notes: Includes data of banks headquartered in the Netherlands at a consolidated level and data of foreign banks operating in the Netherlands.

Figure 16 Sectoral breakdown of direct debt and equity investments of Dutch financial institutions (EUR bn)



Source: Monthly Securities Reporting MER database.

3.2 Implications for banks' credit losses

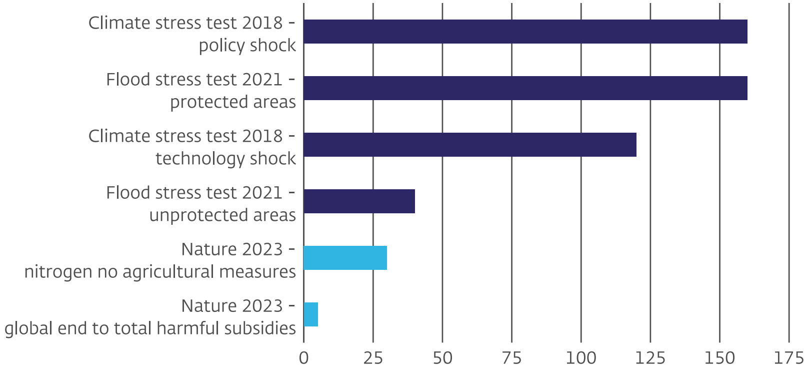
Given the uncertainties surrounding economic impacts, here we only sketch a first assessment of implications for banks. More specifically, we focus on the two nature scenarios that produced the most material economic impacts—the *Nitrogen no agricultural measures* and the *End of total global fossil fuel subsidies* scenarios—given that only they have the potential to cause a noticeable financial impact. Specifically, we estimate the impact of these two scenarios on credit risk, which is usually a main driver of overall financial impact of economic shocks on banks. More specifically, we focus on how credit losses would contribute to a decline in system-wide bank capital. We leave an analysis of impact via increased risk weights for future work.[85]

We estimate a decline in the Common Equity Tier 1 (CET1) ratio for the two scenarios associated with the largest macroeconomic impacts (Figure 17). In red, we report (in basis points) how much the CET1 ratio would decline due to credit losses under the Dutch *Nitrogen no agricultural measures* scenario, i.e. that with limits to construction, as well as the global *Ending total harmful subsidies* scenario. The starting point for these credit loss calculations is per the end of 2022. To place the magnitudes of the impact on credit losses in context, the figure also shows the outcomes for four recent DNB scenario analyses related to climate change.[86] It is informative to compare the results of these scenario analyses given that they face similar methodological challenges (e.g. time horizons, uncertainties, nonlinearities) and that there are strong interlinkages between climate and the broader aspects of nature.[87] While here we only present the outcomes of individual scenarios, it is important to note that in order to get a more realistic estimate of the financial impact of nature-related risks these scenarios would need to be jointly modelled in order to also account for possible amplification channels and second-round effects.

85. This approach of focusing on credit losses follows the transition risk analysis of Vermeulen et al (2018).
86. The results for the policy shock and the technology shock are described in Vermeulen et al. (2018). The results for the two flood risk analysis are taken from Caloia and Jansen (2021).
87. NGFS Central Banking and supervision in the biosphere: An agenda for action on Biodiversity Loss, financial risk and system stability (2022).

Figure 17 Capital depletion due to credit losses

Rounded to multiples of 5 basis points



The two nature scenarios under analysis show limited financial implications. Across the specific scenarios considered in Figure 17, credit losses would generate system-wide capital depletions of between 5 basis points and 160 basis points. Within this scenario set, the indications are that the two nature-related shocks would have effects that are on the low end of the spectrum (5 to 30 basis points).

This initial assessment is a direct reflection of the mild macro-financial shocks generated by the economic models (section 2)**.** Further refinements for the calibration of macro-financial shocks would have direct implications for the calculations on credit losses. Taken at face value, the initial estimates in Figure 17 suggest that the two nature-related shocks under consideration would have limited first-round transmission to credit risk. A main driver of these credit losses are increases in probability of defaults (PDs). In both nature scenarios, these probability of defaults are increasing as the macroeconomy slows down. Relevant drivers of these PD paths include economic growth and unemployment.[88] However, the calibrations for the nature scenarios show only a mild initial decline in economic growth and a moderate increase in unemployment. The estimated impact of the global scenario of *Ending total fossil fuel subsidies* is particularly marginal, as the economic simulations of section 2.1 foresee a strong recovery of the Dutch labor market from year 2 onwards. In terms of credit losses, this means that banks will only have to account for an initial loss in year 1. Subsequently, they can assume that the economic recovery will mean that PDs will return to less elevated levels already. Over this scenario horizon then, overall credit losses are limited.

3.3 Implications for insurers' and pension funds' market losses

For insurers and pension funds, the most impactful scenario when it comes to losses due to change in the market value of the assets is that of ending total harmful subsidies.[89] The impact is approximated by, and therefore also driven by, the changes in the value of equities and risk free rates, as taken from the NiGEM model. The equity price index and the long-term interest rate experience a relatively large initial movement at the onset of the projection, before gradually converging towards an equilibrium. For assessing the financial impact of this scenario, we use this initial movement to approximate the change in the value of bond and equity holdings. Specifically, the two simultaneous and instantaneous shocks we apply based on NiGEM output are:

- A downward shock of 10% on the equity price index, affecting all types and sectors of equities uniformly within the portfolio.

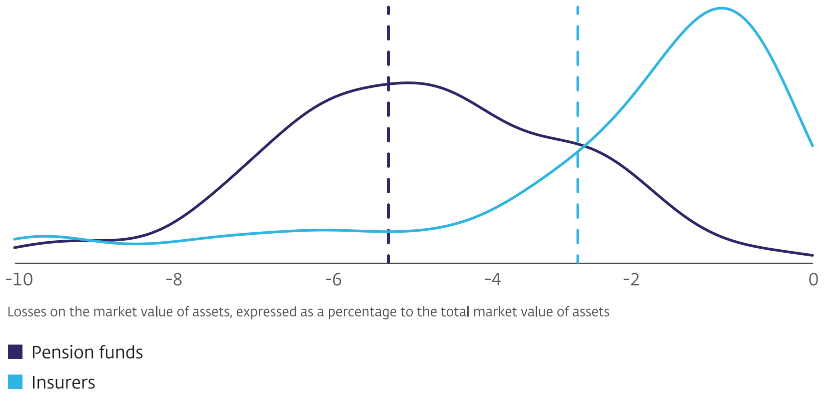
88. See Daniels et al (2017), A top-down stress testing framework for the Dutch banking sector. DNB Occasional Study 15-3.
89. This approach of focusing on market losses on the asset side of insurers and pension funds is also used in the transition risk analysis of Vermeulen et al (2018).

- An upward shock of 0.4% on the long-term interest rate, imposed as a parallel shift in the risk free rate curve, without considering spread risk.

The losses incurred by insurers and pension funds vary widely across individual entities, with a weighted average loss on assets of 3% for insurers and 5.3% for pension funds. (Figure 18) The wide dispersion of losses—with the highest losses amounting to -10% of asset value—is primarily driven by the mix between equities and bonds within portfolios.[90] The higher the share of equity in the portfolio, and the longer the duration of the bonds, the bigger the impact of the shock. In our case, the weighted average loss on assets is 3% for insurers and 5.3% for pension funds. The differences in impact are partly due to the different mix of equities (7.6% for insurers versus 18.1% for pension funds) and partly due to a substantial share of mortgage and loan investments in insurers' portfolios (on average 23% for insurers versus 2% for pension funds). As the mortgage and loan portfolios are not shocked here, this part of the insurers' portfolios is frozen, making the average losses more limited for insurers than pension funds. The calculated impacts do not seem severe when compared to historical data. For instance, recent changes in risk free rates resulted in a loss of the market value of insurers' assets of 16.1% between the beginning of Q1 and the end of Q4 2022.[91]

90. For insures' and pension funds' investments in investment funds, we do not take a look-through approach. Rather, we make the simplifying assumption that these investments are fully made of debt and equity and keep the relative proportion of bonds and equity as in the rest of each entity's portfolio.
91. See Insurance statistics (europa.eu)

Figure 18 Distribution of insurers and pension funds based on losses to the market value of their assets



4 Methodological considerations: choices and scope for improvements

As a first exploration of the impact of nature scenarios on Dutch financial stability, this research has highlighted several methodological limitations and possible improvements when it comes to undertaking such analyses. In this study, these limitations have been binding for the analysis, driving the choice of scenarios, assumptions, modelling approaches, and results. In the hope of adding to the knowledge base of this new field, below we highlight some of the main methodological points. The aim is not to overly criticize individual models. Rather, we hope to contribute to the debate by helping the readers understand the credibility of the results and outlining, based on our experience, fruitful paths for further methodological improvements.

Before outlining the scope for methodological improvements, Table 3 summarizes the types of models used in this analysis, their aim, and their most noteworthy caveats when it comes to interpreting the results.

Table 3 The types of models used in this analysis

Model type	Goal	Noteworthy caveats for nature-related financial risk analysis[92]
Computable general equilibrium (CGE) model	To estimate the (sectoral) economic impact of a global or European nature-related shock on the Dutch economy	■ The model is intended for assessing medium to long-term economic impacts, with the output being a point in time that describes a new equilibrium. Therefore, the results produced are likely to be an underestimation of the potentially more severe short-term impact, as the economy has had time to adjust. ■ The model results do not include all relevant macro-financial information needed to calculate financial losses. Therefore, we always had to use this model in conjunction with a structural model of the global economy (see below).
Input-Output table	To estimate how a sectoral (price or quantity) shock propagates to the entire Dutch economy	■ The model does not allow for substitution effects, making it more suitable for modelling short-term, as opposed to medium to long-term effects. ■ For the EU-27 fossil fuel scenario, the absence of substitution effects also implies that relative (price) changes do not play a role, not allowing for competitive advantages for countries that are comparatively less affected by a shock. ■ For the nitrogen scenario, the lack of substitution between different production factors means that the production structure is assumed to be fixed and that changes in relative prices are ignored.

92. Please refer to section 4 for more information on methodological limitations and scope for improvements.

Model type	Goal	Noteworthy caveats for nature-related financial risk analysis[92]
Structural model of the global economy	To estimate the macro-financial impact of a global nature-related shock on the Dutch economy	■ The model does not have a sectoral dimension. ■ As previously mentioned, this model had to be connected to the CGE model for three scenarios. As the connection between these models is only made through the price effects on five commodity categories, it ignores other detailed macroeconomic information produced by the CGE model.
Semi-structural model of the Dutch economy	To estimate the macro-financial impact of a domestic nature-related shock on the Dutch economy	■ The model does not have a sectoral dimension
Stress-testing model	To translate the macro-financial shocks to losses for Dutch financial institutions	■ The model does not have a sectoral dimension

Including interactions between climate and nature and amplification between ecosystem services would help nature models better reflect stress situations, which are most informative from a financial stability perspective. Even though it is already very granular in many aspects, the nature model used in this study (GLOBIO) does not model interactions and amplifications between different ecosystem services. As a result, worst-case scenarios that would see many ecosystem services decline simultaneously—'multi-dimensional physical risk scenarios'—and give rise to a spiral of nature degradation cannot be modelled yet. This makes modelling tail physical risk scenarios challenging.

We need to connect nature models more broadly to economic models, so as to allow for modelling the economic impact of a broader set of ecosystem services. Ecosystem services that are modelled in nature models are not always connected to an economic model, limiting the choice of even these 'one-dimensional' physical risk scenarios focused only on one ecosystem service. In this study, we focused on pollination decline as an example of a physical risk scenario, as this was the only ecosystem service for which the link from nature to the economic model was done. The limited choice of physical risk scenarios for which an economic impact could be calculated did not allow for a scenario in which the amplifying effects of nature degradation and climate change could be reflected.

There is a need to capture short-term dynamics in nature-to-economy models. Nature-to-economy models are often computable general equilibrium (CGE) models. By definition, CGE models estimate a medium to long term equilibrium. However, in many cases the short-term immediate impact, which is not captured with a CGE model, is the most relevant from a financial stability perspective. The shocks produced by the CGE model used in this study, MAGNET, are likely to underestimate the real short-term impacts. In addition, as it is not possible to observe historical data and volatilities in a model such as MAGNET, it is challenging to get a sense of how much in the tail the shocks are.

Connecting nature-to-economy to pure economic models, which is necessary for a macro-financial scenario that can feed into scenarios analyses, is challenging. Tackling these challenges inevitably involves very strong simplifying approximations. For this study, we needed to map economic estimates produced by the MAGNET model into the NiGEM macroeconomic model in order to generate the macro-financial scenario needed for estimating the losses of financial institutions. The initial shock in MAGNET generates a set of both price and GDP effects. The next step in NiGEM uses the price effects for 5 main commodity categories from MAGNET as a set of exogenous shocks in NiGEM. Subsequent macroeconomic effects are computed solely in NiGEM. While this approach is necessary for generating a fully internally consistent macroeconomic scenario in NiGEM, it does mean we chose to ignore the detailed macroeconomic information produced by MAGNET, such as sectoral movements in value added. This might not always be a fair reflection of reality.

The consequences of the simplifying assumptions of the models used in this report need further attention. To illustrate, we chose to use a default assumption in the NiGEM simulations, namely that agents fully anticipate future changes in market prices. A second assumption we used in the NiGEM simulations is that the fiscal implications of phasing out the fossil fuel subsidy are ignored. Such an assumption is unrealistic, as governments are likely to compensate a tax increase or a decrease in expenditures. Such compensating measures would mute the GDP responses presented in the analyses. Furthermore, neither Magnet nor NiGEM incorporate any saturation limits in terms of the physical world or energy resources. When it comes to the use of the input-output model, there is no substitution possible following a price or quantity shock. In reality, substitution takes place on multiple dimensions, especially in the medium to long term. For instance, consumers will substitute away to relatively cheaper goods, producers will substitute towards relatively cheaper inputs, etc.

When it comes to better assessing financial losses stemming from nature scenarios, developing the sectoral dimension of financial risk models is important. Nature degradation often has a strong sectoral dimension, i.e. the manner and extent to which different economic sectors are affected from nature degradation of a decline in ecosystem services is different. If there are large shocks in sectors to which various financial institutions have large exposures, this will be an important element for assessing the overall impact on the loans and investments of non-financial corporates operating in different economic sectors. This will be an important direction in which risk models can be further developed.

Methodological improvements partly hinge on data availability. While increasing amounts of data are becoming available, data needs still persist. In particular, for better estimating economic and financial risks related to nature degradation, more granular geolocational and sectoral data is key. Such data could, for example, help to better understand how different economic activities depend on nature or how a shock propagates through supply chains.

5 Conclusions and next steps

This study is a first attempt at measuring the economic and financial stability repercussions that a set of tail scenarios related to nature degradation and measures that could be taken to curb it have on the Dutch economy and financial sector. As a learning exercise, it has highlighted several fundamental modelling and data limitations. As the results at least partially reflect these limitations, they should be seen as only indicative and should therefore be interpreted with caution. It is important in this regard to highlight that the muted economic impacts from scenarios *Half-Earth protection*, *Pollination decline*, and *Taxation of EU imports associated with a high risk of deforestation* are likely a result of the modelling choice, i.e. they represent (medium-term) equilibria rather than short-term stress.

A more realistic projection of nature-related economic and financial impact would require that we consider nature scenarios in conjunction. The most informative physical and transition risk scenarios are those that incorporate the multi-dimensionality of nature and the services it provides us. Each scenario presented in this study at best captures one of the dimensions of nature degradation and the policy measures that could be taken in response. Current methodological limitations make it unfeasible to consider these scenarios in conjunction, for example as a set of policy measures taken together to counteract nature degradation. Therefore, the limited impact of many of the scenarios considered likely disguises the real economic impact that would be experienced when policy packages are taken in response to nature degradation (transition risk) or when multi-faceted nature degradation occurs (physical risk). As an example, the increase in agricultural production foreseen in the *Half-Earth protection* scenario for the Netherlands, which is the reason why the country does not experience a strong negative economic impact from the scenario, would likely not be possible if that scenario would be considered in conjunction with the *Nitrogen agricultural measures* scenario.

The multi-dimensional scenarios referred to above would need better nature narratives that translate nature degradation into economic impact, better and more integrated models, and more granular data. Comprehensive nature (degradation) narratives would serve as a basis for developing nature scenarios in which the many dimensions of nature interact to produce a broader economic impact. For this, interdisciplinary knowledge is essential to capture well the dependencies between nature, the economy, and the financial sector. We are yet to discover, let alone quantify, the variety of ways in which nature contributes to human health, labor productivity, etc. In addition, nature-to-economy models need to be able to model the shorter-term, more severe economic impacts of stress scenarios. For this, less favorable modelling assumptions might need to be used, such as lower-than-historical elasticities of substitution between products. Models would also ideally allow for feedback loops between nature, the economy, and the financial sector. Lastly, more detailed data would allow for a more precise quantification of the impact of nature-related scenarios. Nature data, data on the dependency of the economy on nature, sectoral data (e.g. sectoral credit risk parameters), and geolocational data (e.g. of the location of a corporate's operations) would enrich any nature-related financial risk analysis.

The interrelation of nature (degradation) and climate change, as showcased in the *Ending harmful subsidies* scenario, points to the benefits of considering nature and climate change in a more integrated manner. Climate change is one of the main drivers of nature degradation and biodiversity loss. At the same time, nature degradation exacerbates climate change. This climate-nature nexus results in a self-reinforcing feedback loop,[93] pointing to the need to consider these risks jointly. Considering these risks in isolation might underestimate the real impact of climate change and/or nature scenarios.

The estimated results of the tail scenarios considered are largely driven by the methodological choices. The aggregate economic impact of the scenarios *Half-Earth protection*, *Pollination decline*, and *Taxation of EU imports associated with a high risk of deforestation*, is limited for the Netherlands. This is likely due to the modelling choice—through a general equilibrium model –, which produces what would be best described as a medium-term equilibrium rather than a short term stress. In addition, the high competitiveness of the Netherlands partly shields the country from some of these shocks, as agricultural production in the Netherlands increases to compensate for reductions in other countries that are more affected by the shocks. The tail scenarios run through economic models that (also) reflect short-term dynamics suggest a more significant economic impact, though the magnitudes still vary depending on the scenarios. Specifically, the global tail scenario of ending explicit fossil fuel subsidies shows minimal economic impacts for the Netherlands. The global tail scenario of ending total fossil fuel subsidies shows a substantial peak economic impact that declines over time. These

93. Overcoming the coupled climate and biodiversity crises and their societal impacts | Science

results point to the possibility of phasing out all global explicit fossil fuel subsidies without a substantial economic and financial impact for the Netherlands, when this is done simultaneously at a global level. In addition, a more orderly version of our global scenario of ending all global fossil fuel subsidies would likely have a smaller economic and financial impact. The results of the Dutch nitrogen scenario highlight the importance of taking sufficient measures to decrease the nitrogen footprint as a means to avoid a potentially larger economic impact associated with not taking such measures.

Individual financial institutions can mitigate the risks for their portfolio by taking the transition to a nature-positive economy into account. Financial institutions would ideally analyze their exposures not only on a sectoral level, but also on a firm-specific level. The location of the firm's operations and its business model could be as relevant as the sector in which a firm operates.
This information could be used in transition planning. By better understanding the risks associated with their exposures and by taking these risks into account, financial institutions could mitigate these risks and/or alter their investment decisions in a way that also contributes to the transition to a nature-positive economy and decreases the probability of a disruptive scenario.

A timely announcement and orderly implementation of measures taken to protect nature can avoid unnecessary losses. The scenario analysis results suggest that disorderly transitions could have a substantial impact on the economy, both on the directly impacted sectors and indirectly on the whole economy. This also reflects how the impact would be felt for financial institutions. Policy makers can help to avoid unnecessary losses by announcing orderly transition pathways in a timely manner. Postponing the transition increases the likelihood of more severe physical risk shocks and any disorderly transition that will need to be done within a short timeframe in the future.

Appendix I Mapping of commodity groups between MAGNET and NiGEM

Table 1 Mapping the commodity price shocks from MAGNET to NiGEM

MAGNET commodity group	NiGEM commodity group	Geographical area in NiGEM (In MAGNET country-level prices are always available)
Agricultural products	Agricultural raw material prices, index	World only[94]
Beverages and tobacco products	Global beverage prices, index	World only[95]
Oil	Oil price, index	Country & world
Gas	Gas price, index	Country & world
Coal & consumable fuels	Coal price, index	Country & world
Processed/ packaged food and meats	Global food prices, index	Country & world

94. Price movements in agricultural products are very similar between the Netherlands and World.
95. Price movements in beverages and tobacco products are very similar between the Netherlands and World.

Appendix II Sensitivity of macroeconomic impacts

For the three scenarios for which we only have equilibrium results, i.e. the scenarios modelled in the CGE model MAGNET, it is informative to conduct a sensitivity analysis to better understand the impact of potentially bigger short-term shocks. The scenario for which we conduct this sensitivity analysis is *Half-Earth protection with fertiliser tax*. For this, we multiply by a factor of 2, 5, and 10 the price shocks of the commodity groups that we get from MAGNET and use as an input in NiGEM.

We notice that the response in NiGEM is approximately linear, testifying to the lack of (strong) amplification effects in the model. The shock on the five categories of commodity prices produces an impact on GDP of around 1,6 times. The impact is not sensitive to the level of the shock, i.e. the multiplication from 2 to 10 times. (Figure 19, 20)

A scenario comparable to historically stressful events would be that caused by a shock of the magnitude of around ten times the original equilibrium price shocks we get from MAGNET. The scenarios produced using the price shocks taken from MAGNET are not stressful, i.e. have a limited economic impact. To get a sense of what it would take to produce a stressful scenario comparable to past stressful events, we show the macroeconomic response of introducing multiples of the price shocks produced by MAGNET. It seems that an augmentation of the price shocks by around ten times would produce a stressful event comparable to past crises such as the 2008 Global Financial Crisis and/or the COVID-19 pandemic. (Figure 19, 20)

Figure 19 Sensitivity of GDP to multipliers of commodity price shocks

Underlying the scenario half-earth with fertilisation tax

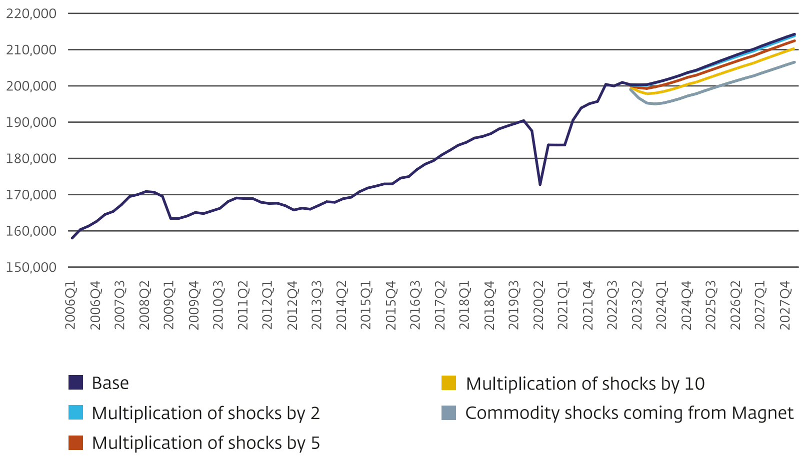
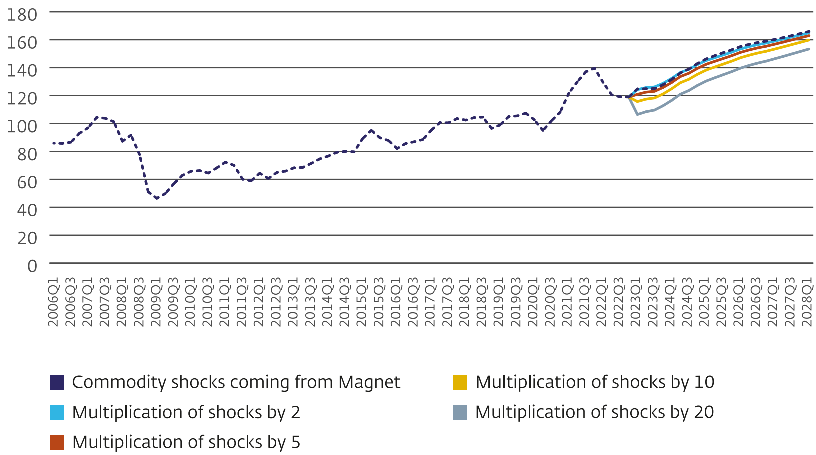


Figure 20 Sensitivity of Dutch equity index to multipliers of commodity price shocks

Scenario half-earth with fertilisation tax



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