Sustainable Finance Platform

The Impact of Carbon Pricing

A financial sector perspective

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This report is a reflection of the deliberations of the Working Group on Carbon Pricing set up under the auspices of the Sustainable Finance Platform. The working group consists of ABN AMRO, ING, MN, PGGM, de Volksbank and Rabobank who took the lead in this project.

The Sustainable Finance Platform is a cooperative venture of De Nederlandsche Bank (chair), the Dutch Banking Association, the Dutch Association of Insurers, the Federation of the Dutch Pension Funds, the Dutch Fund and Asset Management Association, Invest-NL, the Netherlands Authority for the Financial Markets, the Ministry of Finance, the Ministry of Economic Affairs and Climate, and the Sustainable Finance Lab. Platform members meet twice a year to forge cross-sectoral links, to find ways to prevent or overcome obstacles to sustainable funding and to encourage sustainability by working together on specific topics. The Sustainable Finance Platform supports this working group's efforts. However, the practices and advice described herein are in no way binding for the individual financial institutions comprising the industry organizations which are members of the Platform, nor are they committed to take any specific follow-up actions. Furthermore, this paper outlines private sector initiatives and as such does not contain any supervisory requirements or government positions.

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Executive Summary

This report is a reflection of the deliberations of the Working Group on Carbon Pricing set up under the auspices of the Sustainable Finance Platform and was written by ABN AMRO, MN, PGGM, de Volksbank and Rabobank. The cooperation was led by Rabobank.

The findings presented in this report take us one step further towards developing a deeper understanding of the impacts of carbon pricing on the economy and on the financial sector and help us to identify areas which require further in-depth analysis.

For the purposes of this report we use the World Bank definition of carbon pricing. Our research and analyses focus on two pricing mechanisms: carbon taxation and Emissions Trading Systems (ETS).

The report is divided into two sections. Part I contains an analysis of the impact of a carbon tax on economic sectors and the macro-economy with a main focus on the Netherlands and Europe. In addition, the possible impact on the Dutch agricultural and horticultural (sub)sectors is discussed. Part II consists of different perspectives on carbon taxation and the EU ETS from the five cooperating financial institutions. The key take-aways of the report are:

Part I: Macroeconomic analysis with the GTAP general equilibrium model and deep dive into agriculture sector

From a macroeconomic point of view, the impact of a European compared to a national carbon tax would be broadly similar for the Netherlands

The impacts of a CO_2 tax (on combustion-related emissions) with different regional scopes, were assessed against a baseline for 2030 (based on the emission projections of the 'current policy' scenario of the UNEP emissions gap report of 2019). The results of this quantitative analysis by Alexandra Dumitru, Barbara Kölbl and Karolina Ryszka (Rabobank) indicate that the negative impact of a CO_2 tax on Dutch GDP would be similar whether the tax was introduced in the Netherlands only or across Europe (EU + EFTA + UK, referred to as "EU+"). General equilibrium (second round) effects in the model are the reason for this result. More specifically, on the one hand the EU-wide implementation of the tax would allow the Netherlands to regain competitiveness as it would not be taxed alone, but on the other hand the Netherlands would experience a decline in the demand for Dutch exports (compared to the baseline) due to the negative impact of the tax on the EU+ regions.

A carbon tax beyond EU borders could, however, benefit the Netherlands

If the CO_2 tax was imposed on major economies outside the EU+ region as well, the outcome could be beneficial for the Netherlands at a macroeconomic level. In this scenario, GDP for the Netherlands is projected to be higher than in the baseline. Underlying this outcome we also see higher exports from the Netherlands to EU+ and non-EU+ regions. This is likely the effect of competitive advantage gained due to the lower carbon intensity of the Netherlands compared to major economies like the U.S. and China.

In the EU+ region, Greece would be hardest hit; beyond EU+ China would face the biggest impacts

Within the EU+ regions, Greece appears to be negatively affected regardless of whether a carbon tax is introduced at the EU+ level or beyond. Greece would be hit hardest within the EU+ region, according to calculations of the GTAP CGE model, due to its high emission intensity. Some sectors of the Greek economy would even exhibit double-digit declines in output compared to the baseline – among them water transportation and petroleum & coal products. Most countries outside the EU+, especially China, would experience negative consequences for their economies if a CO_2 tax was introduced in major economies beyond the borders of the EU+. Still, failing to reduce CO_2 emissions is likely to have even more negative effects.

Sectoral impacts would vary significantly

Sectors with high direct or indirect carbon emissions would be hardest hit. Imposing a tax on CO_2 from combustion showed that the strongest decrease in output compared to the baseline would be seen in the Dutch power generation sector (constrained by the limited substitution options to low-carbon technologies), air transport and the chemical sector. While it comes as no surprise that these sectors would be impacted the most, this analysis shows the importance of looking at impacts on the sectoral level. Aggregate macro results can mute strong variations on the sectoral level and the absence of a detailed sector view makes it difficult to identify risks. In this respect, further refinement of (sector) results is vital. For instance, the model does not account for endogenous technological change and substitution to low-carbon technologies. This biases the results upwards. Also, the model takes only CO_2 from combustion into account, thus not all anthropogenic greenhouse gas types from all sources are covered, which biases the results downwards.

In Dutch agriculture, the dairy, veal, pork and greenhouse vegetables sectors would be most at risk

Harry Smit and Stefan van Merrienboer (Rabobank) analysed the impact of carbon prices on agriculture in the Netherlands. They indicate that, due to their emission intensity, dairy, veal, pork and greenhouse vegetables would be the subsectors most impacted by a carbon tax.

Before a tax can be implemented for Food & Agri, more insight is needed into emissions from agricultural processes

These authors argue that a carbon tax on agricultural products at this time would not work effectively as there is insufficient insight into carbon emissions from agricultural processes. Without this, introducing a carbon tax would result in a situation where farmers' only option to steer practices towards lower emissions would be to reduce their overall activities.

It is very complex to measure greenhouse gas (GHG) emissions at individual farm level. Emissions can only be estimated by applying standardised emission factors to agricultural processes. To lower GHG emission, farmers can, in theory, switch towards practices with lower emission factors. However, in reality, for many processes the estimates of emission factors of the various agricultural practices are not yet consistent and robust.

Carbon taxing should be applied internationally to deliver the intended results

It is crucial to introduce such a tax at a European level, at the very least to prevent leakage of carbon emissions to other countries. If farmers in the Netherlands were the only ones to reduce their livestock production, farmers elsewhere would take over production, very likely in less resource-efficient production systems, which would therefore increase GHG emissions at a global scale instead. In that case, a carbon tax might have the unintended effect of increasing emissions at the global level

Changes in diets and global approaches to effectively reduce emissions in F&A are necessary

When society makes a switch in its diet (accepting lower consumption of meat and dairy products in exchange for more plant-based alternatives), GHG emissions of livestock farming can be reduced more substantially. This requires an approach at a much larger, possibly global, scale. Finally, the authors argue that a carbon tax on food production may have unwanted side effects. For example, some food products with a low GHG footprint and low nutritional value could get a lower relative price and might drive consumers to a less healthy diet, which as a result would indirectly affect health costs for society. These adverse side effects need to be investigated in more detail and mitigated separately where possible.

Part II: Different perspectives of financial institutions on carbon taxation

Country and company emissions data must be accessible, national statistical offices play an important role

Michael Kurz and Han van der Hoorn (PGGM) discuss the quality of emissions data and of reporting at company level. They argue that the financial sector has a key interest in corporate GHG-emissions disclosures, as financial services firms use this data to calculate and manage the carbon footprint of their investment portfolios. Banks, insurers, asset managers and pension funds rely heavily on high-quality country-level GHG-emissions data to understand the implications of climate-change mitigation policies in the broader economy. They also rely on high-quality GHG-emissions data from companies to effectively guide investment.

Country-level GHG-emissions data is compiled by national statistical offices using different approaches to those used by companies to report their own GHG-emissions data. Current methods therefore do not allow data on companies' GHG emissions to be merged with country-level data. Macroeconomic models used to analyse the impact of climate-change mitigation policies on economies are based on country-level GHG-emissions data. Although the data quality of country-level GHG-emissions data varies according to the methodological refinement of national statistical offices, a minimum level of data quality is guaranteed by reporting guidelines issued by the Intergovernmental Panel on Climate Change (IPCC).

There is a good Carbon Disclosure protocol, but accounting by companies leaves much to be desired

According to Kurz and van der Hoorn, the Carbon Disclosure protocol provides guidelines for the consistent accounting of companies' GHG emissions, but the accounting of GHG emissions remains a complex exercise. As a result, companies' GHG-emissions data is still incomplete, reporting is often not mandatory and there is only limited certainty about reported emissions. Their analysis looks mainly at firms.

Smaller companies, in particular, do not have the technical expertise and resources to implement proper GHG-emissions measurement, and the reliability of GHG-emissions data is likely to be higher for 'green' companies, the authors conclude.

New technologies must be stimulated and carbon pricing should be implemented gradually

Hans van Cleef (ABN AMRO) discusses the impact of carbon pricing on the energy transition. He observes that in its ‘Fit for 55’ plan, the European Commission proposes a major revision of the EU ETS in order to meet the new emission reduction targets. In addition, the Dutch government introduced a carbon tax ahead of the Fit for 55 plans. Van Cleef concludes that carbon pricing could speed up investments in the transition, but only up to a certain level. The question is whether companies falling under the EU ETS actually need a national carbon tax on top of the EU ETS. A national tax could indeed speed up the local energy transition but, at the same time, it could frustrate the working of the EU ETS. If a fast-rising carbon price were to translate into higher consumer prices it would also result in upward inflationary pressure and reduced purchasing power. Van Cleef argues that this could trigger unhelpful and possibly even counterproductive side effects.

New technologies must be stimulated and demand for carbon-neutral alternatives must be supported. Otherwise the main effect of carbon pricing would just be to make the existing energy mix more expensive. Fit for 55 is therefore to be considered an important next step for EU ETS, and a national tax could be helpful for Effort Sharing Regulation (ESR) sectors. Under the ESR, the EU-wide emissions-reduction effort is shared between all the EU Member States. This is done mostly on the basis of a country's wealth as measured by GDP per capita.

Still, it is difficult to achieve this energy transition without providing a way to induce commercial companies to invest in alternatives that are, as yet, unprofitable. Carbon pricing is therefore only one half of the solution.

Return on equity versus return for society

Frans Wernekinck (de Volksbank) states that financial institutions can have a direct and positive effect on reducing GHG emissions by shifting their view from simply looking at return on equity to a combination of return on equity and 'return for society', by which the return for society stands for the positive impact an investment has on the environment or society as a whole. Actions focused solely on reducing GHG emissions would not help to halt biodiversity loss, which could have major consequences. This, in turn, would not lead to the desired result of the Paris Agreement, namely to ‘stop climate change in order to save the planet and its lifeforms’. Financial institutions should therefore look beyond the amount of emissions reduced or avoided and consider a holistic view of the environment when making investment decisions.

Impact of two carbon-price scenarios considered in more detail for the financial sector

Guusje Delsing (Rabobank) discusses the impact of carbon-emission pricing measures on the financial system. She highlights that these impacts could make themselves felt either through lower corporate profitability or the devaluation of assets, or through macroeconomic changes. Two key factors determine this impact: 1) the vulnerability to the impact of such pricing, which she assesses by looking at the emission intensity of sectors at a country level and 2) the likelihood that countries will implement policy, which she assesses by looking at the stance of various countries and sectors towards carbon taxing in the short- to medium-term. The selection of sectors and countries included in this analysis reflects Rabobank's largest corporate exposures.

The author concludes that there is great variability in both the likelihood and vulnerability across sectors as well as countries/regions. The transition risk is highest for sectors with high emission intensity located in countries where a carbon tax (or other transition policy) is most likely and substantial. As a result, transition risk measures such as carbon taxing will have the highest impact on these emission-intensive sectors.

Listed portfolios show vulnerability to transition risk of higher carbon prices

Robbert Lammers (MN) looked at the extent to which portfolios or asset classes are vulnerable to climate risks. He highlights that this depends not only on the speed of transition and the underlying sector or regions, but also on the risk profile of the particular asset class. Moreover, he explains that a listed equity portfolio with 50% exposure to these sectors will probably be more affected than a corporate bond portfolio with the same sector exposure. For an equity investor, a carbon tax has a potential impact on future cash flows, which, generally speaking, will decline once the costs increase. The main issue for bond investors is whether the probability of default (PD) will increase during the remaining life of the bond. PD will increase significantly only if the extra expected costs are so high that the survival of a company is endangered.

The expected relative vulnerability of listed equity portfolios to climate transition risks has led Lammers to interpret the model results with equity portfolios in mind, by mapping the results on listed equity benchmarks. In spite of some caveats and model limitations, the research describes some clear vulnerabilities by identifying those sectors that represent both a significant part of the total market cap of a benchmark and show a significant modelled decline in economic output. Identification of sectors that are highly exposed to climate risks may serve as a guide for further research and ultimately aid the process of benchmark- and portfolio construction.

At the end of the report we present a conclusion, a glossary of terms and a list of all sources consulted.

Forewords from DNB and Rabobank

Foreword DNB

We need ambitious climate policies to reduce carbon emissions and achieve the climate targets of the Paris Climate Accord. As an important part of the policy toolkit, carbon pricing must be enhanced. Because even though carbon pricing has improved significantly in the past decade in many countries and expanded to new sectors, the price of carbon emissions still fails to adequately reflect their environmental and social cost. While other climate policy tools such as regulations and subsidies play an important role in practice, emissions pricing is the most efficient way to reduce them. Such a tax creates market incentivises emission reduction, given that consumer behaviour, investment decisions and production processes are sensitive to emissions prices. It will also stimulate climate investments by improving their business case.

The good news is that there are several proposals for better carbon pricing, for example as part of the EU's "Fit for 55" climate plan. In addition, the price of emission rights in the EU ETS has increased significantly over the past two years. However, due to their negative impact on competitiveness and concerns about carbon leakage and rising consumer prices, support for the introduction of a higher emission tax is often lacking in practice. These are valid concerns that can be addressed by a better understanding of the economic impact of carbon pricing. The number studies on this topic has increased recently, including several studies on the impact of carbon pricing on the macroeconomy which DNB has published. However, there is still much to learn, which is why I wholeheartedly welcome this report.

This report gives us some new and important insights into the economic effects of European carbon pricing on the Dutch economy. Perhaps counterintuitively, it finds that the negative effects to Dutch GDP of a Europe-wide carbon price very similar compared to a tax implemented only at Dutch national level. Such findings add important insights to fuel the ongoing debate about the effects of carbon pricing mechanisms and, more importantly, they show areas in which further research is desirable. In addition, the report provides a comprehensive analysis of the potential impact of carbon pricing on the Dutch agricultural sector. This analysis highlights several elements that may hamper the practical effectiveness of carbon pricing. Among other things, the authors point out that a large fraction of greenhouse gas emissions in the agricultural sector is currently difficult to measure and that carbon pricing may lead to carbon leakage as many agricultural subsectors are characterised by fierce European competition. While these arguments definitely hold water, we should not stop our thinking just there. For instance, excise taxes on animal products imposed on consumers may mitigate leakage problems, and technological developments may reduce measurement problems in the near future.

Furthermore, the report shows that carbon pricing can impact financial institutions through their investments and loans. As a supervisor, we therefore expect financial institutions to assess and understand whether and to what extent they are exposed to this transition risk. This study provides useful insights for financial institutions with respect to ways in which this can be done. To manage these risks effectively, high-quality data is indispensable. This study also shows that corporate disclosure on carbon emissions must be improved. In this connection, I find it encouraging that corporate sustainability accounting standards are being developed both at the European and global level. Lastly, the study rightly points out that while a carbon price will lead to transition risks in the near term, implementing effective climate policies now will prevent both transition and physical risks in the future.

It gives me great pleasure that the Sustainable Finance Platform has been able to facilitate the collaboration between Rabobank, ABN AMRO Bank, ING, MN, PGGM and de Volksbank, resulting in this report. Cooperation and the exchange of information are essential to build up the knowledge required to green our financial system and stimulate sustainable finance. This is the very goal of the Sustainable Finance Platform.

Olaf Sleijpen
Member of the Executive Board of De Nederlandsche Bank (DNB) and chair of the Sustainable Finance Platform

Foreword Rabobank

This report aims to provide new insights in the field of greenhouse gas emissions pricing. The contributions examine the potential impact of various scenarios for business sectors and financial institutions with both quantitative and qualitative analyses.

Rabobank has taken the initiative for this report, and I am very pleased with the broad collaboration over the past two years between researchers from our bank, ABN Amro, ING, MN, PGGM and de Volksbank.

At Rabobank we support the concept of emissions pricing and - provided it is well implemented - we consider it an effective and efficient instrument to help accomplish the Paris goals. The approach should be ambitious, as the situation is urgent. Therefore it is important to start early and to have the full economy in scope. In many parts of the world a start with carbon pricing has already been made, for example the ETS in Europe. Now it's time to expand on this.

We believe that if business and financial institutions take timely action, a gradual and controlled transition to a greener and more sustainable economy can be achieved. Carbon pricing is a way to incorporate true cost and is also an opportunity that gives frontrunners a competitive advantage. Emissions pricing can thus also be seen as a catalyst for transformation and positive change.

Legislation is imperative to make it work. The European Green Deal and the European Climate Act provide clarity in Europe about what is expected from the business community. In the United States, New Zealand and in many other countries there are also developments in regard to emissions pricing. At Rabobank, we follow these developments closely and we engage about the sustainable finance agenda with governments everywhere we operate.

I trust this report contributes to further insights in this complex debate and that you will join me in thanking the participating researchers and institutions for their efforts.

Wiebe Draijer
Chair of the Managing Board of Rabobank

Introduction

By Bouke de Vries (Sustainability Department, Rabobank)

The adverse effects of climate change are becoming increasingly visible and the warnings in the most recent IPCC report are clear. Governments and companies are therefore increasingly taking initiatives to protect society and the economy. Even though it is very difficult to reduce carbon emissions in time, it is still possible to stay on a path of one-and-a-half degrees. Now it is above all a matter of putting words into action: move from talking to implementation.

In May 2019, the Senate of the Dutch Parliament passed a Climate Law that implements the Paris Agreement. Later that year, in July, the Dutch government and the main societal stakeholders agreed upon a national Climate Agreement to help accomplish the necessary carbon reductions. The Climate Agreement describes the main carbon reduction measures for each economic sector and the megatons reductions that are to be achieved up to 2030 and beyond. The Dutch financial sector has supported this Agreement with its own Climate Commitment. It has begun reporting emissions for its portfolios, estimating climate-related risks, conducting stress tests, and formulating transition plans to adequately articulate climate goals and strategies. In 2022, these goals and strategies will be disclosed. The Dutch initiatives are similar to those taken across the globe.

Carbon-emission pricing, the subject of this report, is a potentially powerful instrument in helping to transform our economy towards the desired low-carbon economy. Carbon emission-pricing allows the market to effectively allocate and reduce emissions, provided that governments set caps or taxes in such a way that emissions are actually limited in quantity, and that the price of emitting for companies increases over time.

Companies are expected to respond to carbon-emission pricing by reducing emissions in their production processes and in their value chains, to lower their production costs. Consumer behaviour is also expected to be influenced by carbon-emission pricing. After all, consumers would rather avoid paying a high price for emissions associated with products or services and substitute for low(er) carbon alternatives. Investments are affected by carbon-emission pricing as well, because companies with low(er)-carbon production processes are required to buy less emission rights or pay less carbon taxes. This gives them a competitive advantage, allowing them to attract more investment.

We still have a way to go for carbon pricing to become really effective, and the more knowledge that can be developed and shared about best designs of emissions pricing and impacts on the economy, the better. This clarity is also important to financial institutions as they provide finance to the real economy. That is why in 2019, Rabobank took the initiative to set up a working group that researches this topic in the framework of the Sustainable Finance Platform, a cooperative venture of De Nederlandsche Bank (chair), the Dutch Banking Association, the Dutch Association of Insurers, the Federation of the Dutch Pension Funds, the Dutch Fund and Asset Management Association, Invest-NL, the Netherlands Authority for the Financial Markets, the Ministry of Finance, the Ministry of Economic Affairs and Climate, and the Sustainable Finance Lab. The participants in this specific Working Group on Carbon Pricing were Rabobank, ABN AMRO, MN, PGGM, ING and de Volksbank. Their collective efforts are presented in this report, which was written by Rabobank, ABN AMRO, MN, PGGM and de Volksbank.

The report has the following structure: Part I contains an analysis of the impact of a carbon tax on economic sectors and the macro-economy with a main focus on the Netherlands and Europe. In addition, the possible impact on the Dutch agricultural and horticultural (sub)sectors is discussed. Part II discusses five thematic topics: data quality and disclosure, the impact of carbon pricing on the energy transition, engagement of financial institutions with companies to reduce emissions, a bank's risk perspective on carbon taxing, and the relevance of a carbon tax for listed equity. The report ends with a short conclusion.

PART I: THE IMPACT OF A CARBON PRICE

1. Economic impacts of a carbon tax

Authors: Alexandra Dumitru, Barbara Kölbl**, Karolina Ryszka****

The COP26 president concluded the negotiations with the statement:
"We can now say with credibility that we have kept 1.5 degrees alive. But, its pulse is weak and it will only survive if we keep our promises and translate commitments into rapid action." Rapid action to mitigate GHGs can come in the form of different policies. A prominent policy tool to mitigate GHG emissions is a carbon price. An instrument, whose "potential […] is still largely untapped" (World Bank, 2021 p.8). With mitigation action becoming more urgent, it is also becoming increasingly important for policy makers, companies and financial institutions to understand the economic impacts of such policy actions.

One way of putting a price on emissions is to tax the amount of emissions that are released. To provide insights for policy makers, companies and financial institutions on the possible economic effects of a carbon tax, this research looks at introducing a carbon dioxide (CO_2) tax (of USD 100 and 150) with different regional coverage. The effect on macroeconomic variables such as GDP and trade, both at sector and country level, are analysed. We particularly highlight the economic effects of a carbon tax in the Netherlands, but also look at the impacts on other EU countries and beyond.

1.1 Model set up and scenario definition

1.1.1 Methodology

The economic effects of a carbon tax are quantitatively assessed using the computable general equilibrium (CGE) model GTAP-E. CGE models allow us to analyse the economy-wide and sector-specific effects of external shocks and policy changes. The interaction between product, factor and international markets is modelled using neoclassical economic optimization theory. A policy change leads to a re-matching of supply and demand by adjusting prices until a new equilibrium is reached. An equilibrium is reached at the price where supply equals demand. This has to be the case simultaneously in each market of the economy.

The GTAP database distinguishes several regions and sectors (65 sectors and 121 regions). In this analysis we used a somewhat higher aggregation of sectors and regions which is described in Appendix II. GTAP-E is an adjusted version of the standard GTAP CGE model: it also allows for energy substitution which is a vital feature for this study. For a more detailed explanation of the GTAP-E CGE model see Appendix I.

As the model is only directly linked to fossil fuel combustion-related CO_2 emissions (see 1.1.4), we only apply a carbon tax to CO_2 from the combustion of fossil fuels. Hence, the scenario outcomes reflect the impact caused by a carbon tax to drive the energy transition, while leaving out other processes and other greenhouse gases (GHGs). This means that CO_2 from industrial processes and other GHGs are excluded from the simulations. Therefore the quantitative analysis will not capture the complete impact, especially in sectors where other emissions play a significant role: for example in the agriculture sectors. To address this constraint for the

* *RaboResearch: in her role as Senior Economist Climate Change until 5 December 2021*
** *RaboResearch: Sustainability Economist*
*** *RaboResearch: in her role as Economist - Energy Transition and Circular Economy until December 2020*

agricultural sector, Chapter 2 of Part I takes a fact-based qualitative approach to assess the impact on the agricultural sector where GHG emissions are driven by non-CO_2 gases.

1.1.2 Defining the model baseline

Like most modelling work, the GTAP CGE model needs a baseline or reference scenario against which the effects of a carbon tax are assessed. The choice of the baseline is crucial for the policy assessment and the question is which assumptions should be made about how the world will develop. The future is generally characterised by uncertainty so the baseline should be seen in that light; and the current global pandemic increases the level of uncertainty of any predictions.

The model is not suitable to provide forecasts of growth rates or levels. Instead, it provides insights into possible impacts resulting from exogenous policy shocks relative to a baseline. Baseline scenarios are not intended to predict the future, but they are counterfactual constructions that can serve to highlight the effects of a shock or a policy change. In this report, we stick to the convention of modelling baseline scenarios on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force (i.e., a Business-as-Usual scenario).

The base year of the GTAP-E database is 2014. To construct the baseline, we use data projections for GDP, labour population and emissions changes from OECD, World Bank and UNEP Emission Gap report 2019 (for details and data sources see Appendix III: Data and main assumptions). Regarding the emission levels in the baseline, we use the "current policies" projections provided by the UNEP's Emissions Gap Report 2019, as these were the most recent 2030 projections at the level of individual countries when we ran the simulations (in 2021). At that time those baselines were on the low end of the Intergovernmental Panel on Climate Change (IPCC) no-policy scenarios. The UNEP current-policies estimates projected total GHG emissions to reach 60 $GtCO_2e$ in 2030, which corresponded to a world on its way to warming up by way more than 3 degrees Celsius. In fact, even the full implementation of the unconditional Nationally Determined Contributions (NDCs) was expected to steer the world towards global warming of 3.2 degrees Celsius by the end of the century with a probability of 66%. The 2030 emissions associated with this scenario was expected to be about 56 $GtCO_2e$ in 2030 (UNEP 2019). It should be noted that the current-policies projections of the UNEP Emissions Gap Report 2021 give emission estimates for 2030 of about 55 $GtCO_2e$. The difference is partly justified by emission reductions realised on the back of the Covid-19 pandemic and partly by policies implemented and accounted for by studies in the meantime.

It is an important caveat that we do not include measures that have been approved since the end of 2019 (e.g. the Dutch national CO_2 industry tax implemented in 2021, though the impact is likely modest given the increase in EU ETS prices in the past year). The limitation here is the fact that the UNEP Emissions Gap Report 2019 was the most recent source (at the time) that translated current policy to 2030 emission levels at the country level for a large group of countries (the G20). Additional estimates of new policy impacts were beyond the scope of this study.

We also note that, in line with our current policies scenarios, additional pledges are not included in the baseline. This includes the plethora of net-zero country targets announced in recent years as most of these targets have not been translated to measures that are enshrined in law. This of course includes the revisions of adopted targets (including the revised NDCs) such as the EU's 55% 2030 emissions-reduction target.

Finally, in the stylized economic model we model a carbon tax which then also incorporates the EU Emissions Trading System (EU ETS) price. In theory one can regard the carbon tax as a carbon price – both should work the same way, despite the fact that the ETS price is volatile and the carbon tax is fixed. Scientific literature uses carbon pricing as a term encompassing both a price resulting from an ETS and a carbon tax (World Bank; IPCC, 2014). In practice, the EU ETS 2018 revision is included in the 2030 projection by the UN which was used for the 2030 baseline of this modelling exercises. While the exact development in recent years (i.e. the recent rise in EU ETS prices) might not have been anticipated, in principle, average expected long-term price increases must be contained in these projections. We therefore assume that the carbon tax applied in this study accounts for emission reductions that are not induced by the EU ETS (i.e. emission reductions additional to the reductions already accounted for in the emission projections of the baseline).

1.1.3 Describing the model scenarios

Introducing a carbon tax

We discern two ways in which emissions can be priced: through a CO_2 tax or by setting up a cap-and-trade system (an emissions trading system). With a CO_2 tax, the price of emissions is set and the market will then determine the amount of GHG that will be emitted. In an emissions trading system, it is the amount of emissions that is fixed and the market determines the price. In an economically perfect world, the outcome of both systems would be the same: the same emission with the same CO_2 price. In reality, there is uncertainty within both systems: in the case of a carbon tax, it is not easy to predict in advance the exact emission reductions that the tax will trigger; in the case of a carbon trading system, it is difficult to estimate at which CO_2 price the market will clear.

Hence, in both cases it is difficult to estimate the level of policy that will have the desired outcome, namely: how high the carbon tax should be or how many emission permits should be issued, respectively. The economic and climate models designed to estimate these levels are characterized by many uncertainties, among which climate-related estimates perhaps exhibit the highest level of uncertainty. The range of estimates for the prescribed level of CO_2 prices is very wide: 95% of the CO_2 price estimates from the most recent studies are between EUR 10 and around EUR 200 per ton of CO_2. But according to the High-Level Commission on Carbon Prices, a CO_2 price of USD 40-80 per ton was needed by 2020 to meet the Paris targets.
Determining the maximum supply of emission allowances for a specific country or region is even more complicated. The uncertainties make both instruments susceptible to policy errors. We know from empirical data that, in practice, a CO_2 tax is often set too low and the supply of emission permits is often set too generously, resulting in less emission reductions than required. Both systems are also sensitive to lobbying and the influence of vested interests. However, a carbon tax has several advantages over a trading system. A CO_2 tax is more predictable and gives companies and consumers certainty about their costs, which is more conducive for investment and purchase decisions (Kettner, 2011). As mentioned earlier, it is easier to set a tax rate than an emission quantity. Moreover, a CO_2 tax has fewer undesirable interactions with other climate policies (Goulder & Schein, 2013).

Given these advantages, we chose to model the CO_2 price as a carbon tax in this analysis. To stay within the range suggested by the High-Level Commission on Carbon Prices we chose to apply a carbon tax of USD 100 per ton of CO_2. This is also in line with DNB's policy shock scenario in their energy transition risk stress test (DNB, Web-appendix: modelling the energy transition risk stress test). For sensitivity analysis purposes we also apply a tax of USD 150 /tCO_2. This was in line with preliminary NGFS (Central Banks and Supervisors Network for Greening the Financial System) analysis (Berdeen S., Climate change – Plotting our course to Net Zero), though the second set of NGFS climate scenarios places the carbon prices close to USD 200 per ton in a net-zero world.

The geographical areas

In addition to the two different tax rates that we work with, we also introduce three geographical scenarios:

- Scenario 1: The tax rates apply only to the Netherlands;
- Scenario 2: The tax rates apply to the EU, the EFTA countries and the UK;
- Scenario 3: The tax rates apply to all countries in scenario 2 and to other important countries, namely the USA, China, Canada, Japan, Australia and Rest of Oceania (i.e. New Zealand);

We chose to include the EFTA countries (Iceland, Lichtenstein, Norway and Switzerland) in the carbon tax jurisdiction in the second scenario because the EFTA states participate in the EU ETS. We also include the UK because the country was anticipated to stay closely linked to the EU and continue to implement ambitious climate policies. In fact, the UK has decided to roughly replicate the EU ETS system post-Brexit and prices broke through the EU ETS levels at launch in May 2021.

The countries to implement a carbon tax in the third scenario were chosen because they have ambitious climate policies such as a carbon tax or an ETS in place (World Bank, 2020) and are therefore more likely to potentially implement ambitious climate policies in the future.

- Australia: Australia already has an ETS in place.
- Rest of Oceania: New Zealand has a net-zero emissions target in its legislation. Moreover, it has an ETS in place.
- China and Hong Kong: China has the goal to become net-zero in 2060. It launched a national ETS in 2021.
- Japan: Japan has a carbon tax in place.
- Korea: Korea has an ETS in place.
- Canada: Several regions in Canada have ETS in place. There is a national law requiring the regions to implement ETS, otherwise a national carbon tax needs to hold.
- USA: Several U.S. States have an ETS in place. Moreover, the U.S. returned to the Paris Climate Agreement, President Biden announced an emission reduction target for 2030 by around 50% (relative to 2005 emissions) and several pledges were made by the U.S. at the COP26. Also, the USA is of interest to many of the Working Group on Carbon Pricing members, so it is included in the third scenario.

1.1.4 Main limitations of the model

CGE models are complex models, based on neoclassical economic theory. They can be useful for simulations to assess the impact of certain external shocks, such as the introduction of a carbon tax. However, like any model, CGE models abstract from many things which are important in economies in the real world, as the reality is more complex and difficult to reproduce. Some limitations are specific to our study, some driven by characteristics of the GTAP-E model, while others are driven by data constraints.

GTAP-E characteristics

The GTAP-E model can only assess structural long-term changes. The model looks at the economy in a general equilibrium and, after adding a shock, e.g. a policy or a tax, to the original general equilibrium, the model solves to another general equilibrium. Hence, the model captures structural economic changes resulting from an external shock but is not useful for either modelling short-term effects or modelling transition periods (such as a gradual implementation of a carbon tax). The model does not give insight in the path the economy takes to go from one general equilibrium to another. Similarly, the standard GTAP model does not model short-term (year-to-year) fluctuations or business cycles – it is governed by fixed aggregate demand at base-year levels and future trend estimates. Short-term effects may sometimes temporarily be larger than the calculated structural outcomes, for instance due to confidence effects, price stickiness and adjustment costs.

CGE models such as GTAP typically rely on fixed econometrically estimated elasticities as inputs for important model parameters. Model responses to shocks are governed by these elasticities and parameters. These elasticities can vary strongly and there is no consensus on which elasticities to use. CGE models are sometimes criticized for using these off-the-shelf elasticities. However, these uncertainties are to some extent inherent in economic models. Here, we use the elasticities as provided by the GTAP database. To assess the sensitivity of the results to these elasticities, a sensitivity analysis should be undertaken in future research – a sensitivity analysis for the energy-specific elasticities would be most relevant to this study.

There is no explicit modelling of financial markets, but the existence of a financial market is implicit in capital mobility within and across regions. The model reflects the real economy and works with real values. But there are no nominal prices: only relative prices matter. All values in the GTAP database are in USD but real exchange rates are implicitly accounted for by the relative price changes between countries. Other dynamics, such as learning-by-doing, technological and know-how spill-overs and endogenous technological change are not modelled explicitly.

Moreover, since we are not explicitly modelling electricity generation by different power sources, the share of renewable energy is fixed to the base-year values, and these shares cannot be increased. This leads to an overestimation of the impacts, (especially in the electricity sector in regions with high fossil-fuel generation in the base year) as there are no possibilities to substitute away from fossil fuel technologies. This caveat must therefore be kept in mind when interpreting the magnitude of the impacts.

Finally, GTAP-E does not allow to actively steer the recycling of carbon tax revenues. This means that we cannot determine what the tax revenues are used for in the model. Nevertheless, CGE models have a comprehensive accounting of all value flows in the economy and therefore the tax revenue will always be accounted for. In GTAP, the tax revenues in the model are automatically allocated to a representative agent that combines the consumption behaviour of the government and households. Hence, tax revenues are used for consumption by households and the government but it is not possible to steer the consumption to specific sectors.

Data constraints

There is no database of GHG emissions available that is up-to-date, peer-reviewed, fully vetted, published and documented. This is because national and international statistics come out with a lag and the GTAP database is not regularly updated. The newest GTAP-E database depicts the base year 2014 and was released in spring 2020. So researchers have to start with 'out of date' data which they then need to update themselves. Using the data from 2014, we built the baseline based on GDP, population and emissions projections. The 2014 structure of the economy is generally preserved in the projection. Hence, structural changes in the composition of trade and production of the different economic activities in the model after 2014 are not explicitly accounted for in these baseline projections. Important structural changes which are not represented explicitly in the baseline projections include change in natural gas trade. A particular example here is the Netherlands: the changes in the composition of the Dutch economy and trade flows as a consequence of lower domestic natural gas exploration is unlikely to be captured – (the Netherlands shifted from a net exporter of natural gas in 2014 to a net importer in 2018).

Moreover, the model is only directly linked to CO_2 emissions from burning fossil fuels. Linking the GTAP-E to the non-CO_2 database to account for other emissions (e.g. methane or nitrous oxide) is a complex exercise and, due to time constraints, is beyond the scope of this report. Therefore, agricultural emissions remain largely unaccounted for in the quantitative analysis. The same applies for CO_2 emissions which stem from industrial processes.

Some constraints are related to the data we use to build our baseline. The emission reductions projected by the UN are based on all GHG emissions. By using the same change rates for CO_2 fuel combustion emissions we assume that the relative emission reductions in CO_2 from combustion of fossil fuels must be same as the relative reduction of all GHG emissions projected by the 2019 UNEP Emission Gap Report.

Due to the simplifications and constraints described above, the outcome of our simulations should be interpreted carefully. Moreover, the focus of the outcomes is not on forecasting but on the relative changes compared to the Business-as-Usual 2030 baseline. The model should not be used to forecast level or growth rates of the main macroeconomic variables.

1.2 Model outcome and interpretation

In this section we report on the results of the GTAP model calculations. We apply two different carbon tax shocks, namely USD 100 and USD 150, to three regions: (1) the Netherlands, (2) the EU, EFTA and the UK (which we will call EU+) and (3) the EU, EFTA, UK as well as the USA, China, Canada, Japan, Australia and Rest of Oceania (which we will call ALL-). This results in 6 scenarios that we run: CT100NL, CT100EU+, CT100ALL-, CT150NL, CT150EU+ and CT150ALL-. To assess the economic impact of the carbon tax we look at the impact on country real GDP, on output in specific sectors, and on exports.

Different taxes, similar relative impacts. We note that across the board the impact of a 50% higher carbon tax (USD 150 compared to USD 100) leads to roughly 50% larger economic impacts. This is the case for most countries when the tax is introduced only in NL or in the EU+ region. When the higher tax is also imposed outside EU+ we see many outliers: among them Denmark, Greece and New Zealand (Rest of Oceania) see disproportionally stronger impacts in the CT150ALL- scenario compared to the CT100ALL- scenario. In contrast, for Poland the impact decreases in the switch between the two scenarios. The relative impact – which countries or sectors are affected most – remains unchanged.

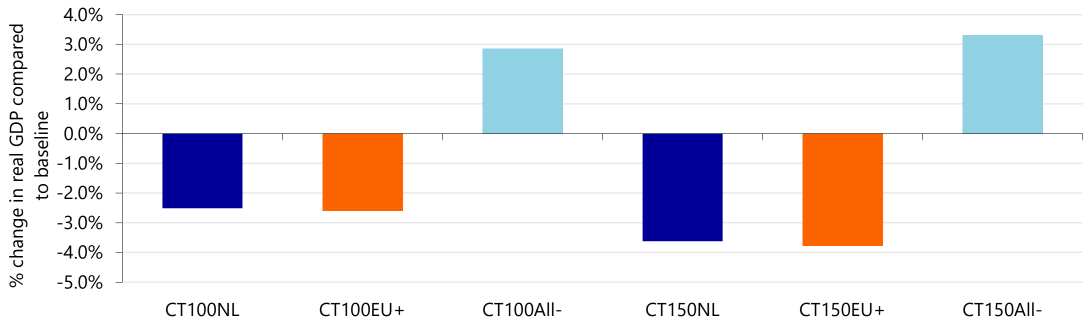
1.2.1 Impact on the Netherlands, a detailed analysis

Macroeconomic effects of different carbon tax scenarios

A CO_2 tax implemented in the Netherlands alone decreases real GDP compared to the baseline. The focus of this study is the Netherlands, so we start with the outcome of the CT100NL and CT150NL scenarios, in which the carbon tax is only introduced by the Netherlands. The model simulations show that under a carbon tax of USD 100, real GDP would be 2.5% lower than in a 2030 baseline without a carbon tax (Figure 1; Figure 2). If the tax was USD 150, real GDP would be 3.6% lower than in the 2030 baseline. While the comparison to the historic impacts in terms of year-on-year changes is not the same as a difference to a baseline (affecting potential GDP, not just the economic growth in one year), it is interesting to see that the impact on the Netherlands even in the more stringent USD 150 tax scenario is not more than the initial impact of Covid-19 on GDP, which was a 3.7% fall in GDP in 2020 (OECD 2021).

If the carbon tax is introduced in the EU+ region, the Dutch economy suffers roughly as much as when only the Netherlands introduces a carbon tax. The outcomes in terms of aggregate macroeconomic impacts for the Netherlands are not significantly different whether the tax is imposed only on the Netherlands or on the whole of the European Union (EU+), as illustrated in Figure 1. The real GDP decrease (compared to the baseline) for the Netherlands in the CT100NL scenario is about 2.5%, and only slightly higher (2.6%) when the carbon tax is imposed on the whole of the EU+ (CT100EU).

Figure 1: Impact of a carbon tax on Dutch real GDP in % changes compared to the 2030 baseline

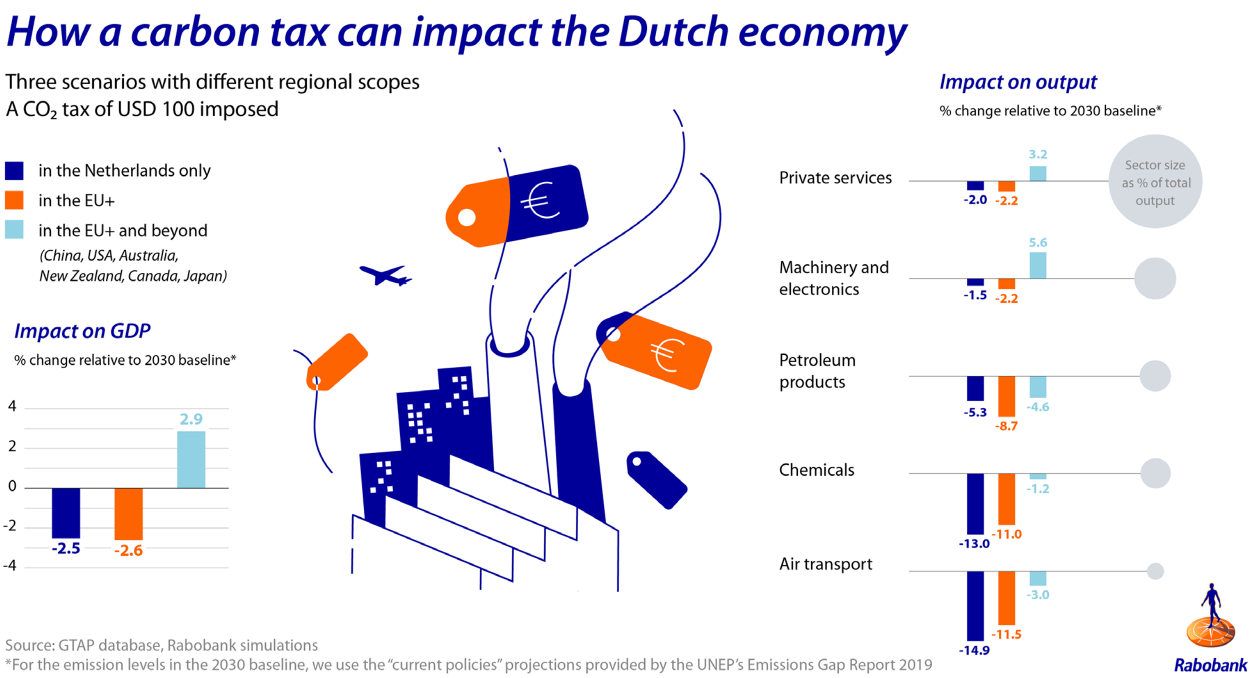


Source: GTAP database, Rabobank simulations

Changes in Dutch exports indicate that general equilibrium effects lead to similar outcomes for the Netherlands if it is taxed alone or as part of the whole EU+ region. If a carbon tax is implemented only on the Dutch national level, one would expect the Netherlands to suffer more due to its loss in competitiveness compared to other EU+ countries. In other words, one might expect a more favourable outcome for the Netherlands in a scenario when the tax is imposed at EU+ level (see e.g. Hebbink et al. 2018). Yet, the outcomes of our analysis suggest that this effect is outweighed by second round (general equilibrium) effects. In fact, total exports from the Netherlands decline by more compared to the baseline, if the tax is also imposed on the whole of the EU+ compared to only taxing CO_2 in the Netherlands (see Table 1 below). This is a result of lower demand for Dutch exports from other EU+ regions: since the introduction of a carbon tax leads to lower GDP compared to the baseline in all these regions, their demand for Dutch exports also decreases. Thus, while the Netherlands might indeed regain some of its competitive advantage with respect to exports to non-EU countries (indicated by a slight increase in Dutch exports to non-EU+ countries when going from the CT100NL to CT100EU+ scenario), the Netherlands would presumably suffer from lower demand for exports from EU+ countries. In other words, the competitive advantage gained outside the EU+ is offset by the decrease in demand for Dutch exports from EU+ regions. Moreover, the introduction of a carbon tax in the EU+ might put additional pressure on the Netherlands through increased input prices for imports from EU+ partners.

The Netherlands gains from a carbon tax introduced beyond the borders of the European Union. When the carbon tax is introduced in the major economies beyond Europe, real GDP in the Netherlands increases by 2.9% under the USD 100 carbon tax and by 3.3% under the USD 150 tax compared to the 2030 baseline. In this scenario exports from the Netherlands increase by 1% above the baseline level (Table 1). This is likely because the tax would increase the competitiveness of the Netherlands compared to the taxed non-EU+ regions (i.e. the additional regions taxed in the CT100All-/CT150All- compared to the EU+ scenarios). In fact, the regions outside of EU+ which are taxed in this scenario are more carbon intensive in the 2030 baseline than the Netherlands.

Figure 2a: Impact of a carbon tax on the Netherlands



This illustration shows the impact on real GDP and on the output of selected sectors in the Netherlands relative to the 2030 baseline. Disaggregation of the sectors illustrates the variation of the impacts per sector, both in strength and direction, which cannot be seen on the aggregate macro level.
Source: GTAP database, Rabobank simulations

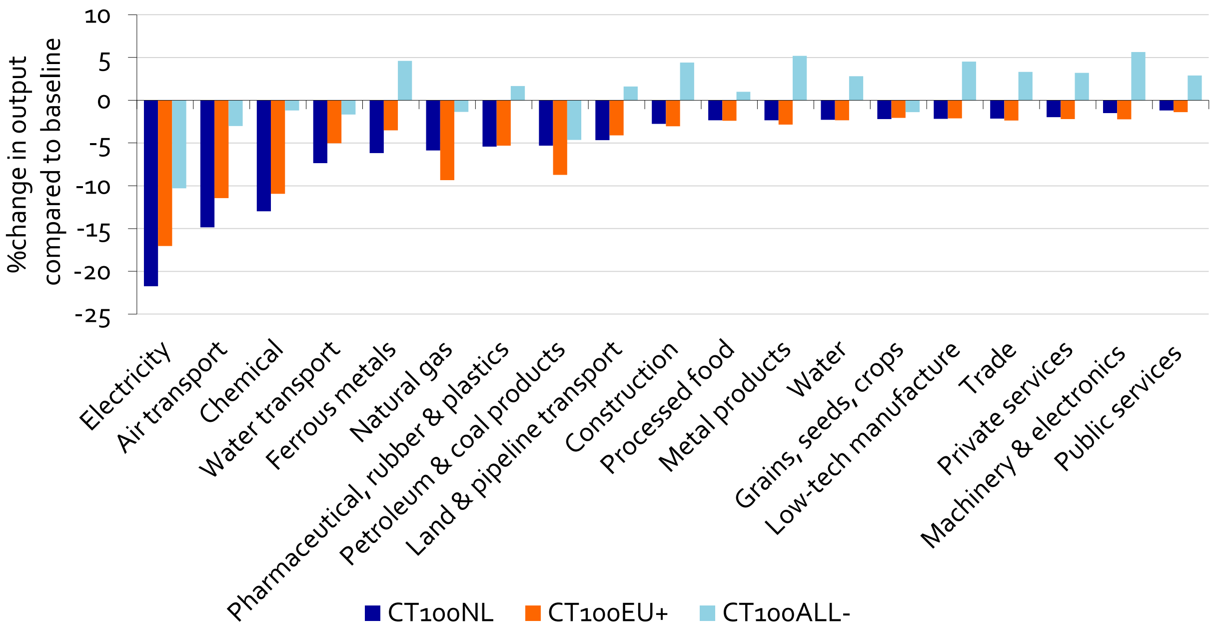
Winners and losers in the Netherlands - A sectoral dimension of the Dutch impact

The most impacted sectors are either CO_2 intensive themselves or use a large share of carbon- intensive intermediate inputs. We observe the strongest impacts in the electricity sector (Figure 2b). As the energy mix in the model is relatively fixed (i.e. the technology mix represented in the 2014 data cannot significantly change endogenously as substitution to renewables is not possible in the model), this outcome should be interpreted carefully; in reality the negative impact on the electricity sector would be softened somewhat by a switch to renewable power. The Dutch air transport sector experiences a strong decline in output compared to the baseline in all scenarios due to its high carbon intensity (here also a switch to less carbon-intensive fuels will be much more difficult in reality as the aviation sector is among the most challenging sectors to reduce emissions (IEA, 2020)). While the chemical sector has comparatively high direct CO_2 emissions, this alone cannot explain the strong impact of the tax in all scenarios. In fact, a further reason for the strong impacts on the chemical sector is the high portion of CO_2 intensive intermediate inputs - among them high inputs from the petroleum products sector, natural gas sector and power production.

The impact on some of the largest sectors is comparatively small and becomes more pronounced when the tax is also imposed on the other EU+ regions. The service sector (private and public services), which is one of the largest sectors in the Netherlands, experiences only a modest fall in output compared to the baseline when the tax is introduced in the Netherlands. In this scenario we find a decline in output of around 2-3% compared to the 2030 baseline (Figure 2a; Figure 2b). Moreover, it is interesting to observe that some of the largest sectors (service sectors, construction, trade, processed food, and machinery and electronics) experience stronger negative impacts on output when the tax is also imposed on the EU+ neighbours than when the Netherlands acts alone. In other words, these sectors lose more in output compared to the baseline when the tax is also imposed on the EU+ neighbours. Together with a stronger decline in exports relative to the baseline in these sectors in the CT100EU+ scenario, this reflects the offsetting negative effects due to lower demand for Dutch exports from EU+ countries that is observed on the macro-level as well.

Extending the carbon price to the whole of the EU+ region can be alleviating for some sectors but not for all. For the top 3 impacted sectors (i.e. electricity, air transport, chemicals) the output decline compared to the baseline when the carbon tax is imposed on all EU+ regions is significantly less severe than when the tax is imposed in the Netherlands alone. However, as discussed in the previous paragraph, some sectors are also hit more strongly in this scenario (Figure 2a; Figure 2b). Nevertheless, this shows that on the sectoral level, it *does* make a difference for some sectors whether the tax is introduced in the Netherlands only or beyond.

Figure 2b: Impacts on Dutch sectors by a CO_2 tax of USD 100 /tCO2 (only sectors with share in output ≥ 0.5% are shown)



Source: GTAP database, Rabobank simulations

A carbon tax on all major economies comes with benefits for some Dutch sectors. While the chemicals, electricity (with the caveat of no renewable-substitution options) and air transport sectors experience a decrease in their output compared to the baseline under all tax regimes (Figure 2a; Figure 2b), the negative impact on their output is alleviated further if the tax is further extended beyond the borders of the EU+ in the CT100All-/CT150All-scenarios. Other sectors that see lower output under a Dutch or EU+-wide carbon tax, may experience an increase in output compared to the baseline when the carbon tax is extended to major economies outside EU+. Interestingly, we see output increases in some of the largest sectors (service sectors, construction, trade, and machinery and electronics) of around 3% to almost 6% compared to the 2030 baseline. These sectors also export more compared to baseline, reflecting the situation found on the macro-level for this scenario.

1.2.2 Impact on European countries

The macroeconomic picture

EU+ economies stand to lose if they remain the only region to introduce a carbon tax. All countries in the EU+ region see their economies shrink compared to the baseline in a scenario where the tax is only introduced there. Greece, Central Eastern European countries and the Netherlands are most impacted in such a scenario (Table 2). The GDP decline (compared to the baseline) for the top 3 most impacted countries (Greece, Poland and the Czech Republic) is much stronger than in most other countries. This is not surprising as these three countries are also the most emission-intense economies in the EU+. The group of least impacted regions is Sweden, France and EFTA. These regions are also characterized by low emission intensity in the baseline.

Trade is also negatively affected across the board among the EU+ countries when the carbon tax is applied only there. Table 1 shows the impacts on aggregate exports for all scenarios. The 3 countries where exports decline most compared to the baseline are Greece (-20%), Portugal (-4.6%) and the Czech Republic (-4.6%). However, the differences between the latter two and the rest of the countries in the EU+ is fairly small, as most countries see exports contracting by 3 to 5% compared to the baseline.

Table 1: % changes in aggregate exports per region compared to baseline 2030

	CT100NL	CT100EU+	CT100ALL-	CT150NL	CT150EU+	CT150ALL-
Greece	0.11	-19.99	-14.81	0.16	-26.34	-20.19
Portugal	-0.02	-4.58	-0.54	-0.03	-6.45	-1.26
CzechRep	-0.04	-4.58	1.51	-0.06	-6.40	1.46
Poland	-0.04	-4.55	0.28	-0.05	-6.44	-0.25
Finland	-0.03	-4.46	-1.92	-0.05	-6.28	-3.03
Netherland:	-3.73	-4.32	0.87	-5.28	-6.16	0.53
RestEU	-0.03	-4.18	0.94	-0.04	-5.96	0.61
Italy	-0.01	-4.14	-0.38	-0.01	-5.86	-1.02
Spain	-0.01	-4.01	-1.96	-0.01	-5.63	-3.01
Hungary	-0.02	-3.81	1.06	-0.03	-5.45	0.87
Belgium	-0.25	-3.79	0.63	-0.34	-5.41	0.27
Romania	-0.02	-3.69	2.88	-0.03	-5.29	3.24
Germany	-0.05	-3.32	-0.84	-0.07	-4.66	-1.47
France	-0.02	-3.24	-1.37	-0.03	-4.57	-2.16
Austria	0.00	-3.20	0.36	0.00	-4.54	0.05
Denmark	0.00	-2.64	-0.80	0.00	-3.75	-1.39
UK	-0.05	-2.57	-0.04	-0.08	-3.64	-0.39
Sweden	-0.01	-1.95	0.35	-0.01	-2.80	0.19
Ireland	0.02	-1.59	2.92	0.03	-2.28	3.57
EFTA	0.01	-1.04	1.19	0.01	-1.48	1.45
Russia	-0.05	-0.57	0.96	-0.07	-0.78	1.17
SaudiArabi:	-0.01	-0.15	1.14	-0.02	-0.21	1.51
Turkey	-0.03	-0.10	6.17	-0.04	-0.14	8.14
CHG	-0.01	-0.07	-3.47	-0.01	-0.10	-5.32
Iran	-0.02	-0.07	1.99	-0.02	-0.09	2.46
USA	-0.01	-0.06	1.17	-0.02	-0.08	0.40
Brazil	-0.01	-0.04	0.43	-0.01	-0.06	0.53
Australia	0.00	-0.03	-0.29	0.00	-0.03	-0.98
SouthAfrica	-0.03	-0.03	3.71	-0.04	-0.03	4.88
ROW	-0.02	0.03	3.01	-0.02	0.04	4.00
Indonesia	-0.01	0.05	1.16	-0.01	0.06	1.39
India	0.01	0.06	0.80	0.01	0.09	1.07
Japan	-0.01	0.11	-4.02	-0.01	0.15	-5.91
Canada	0.00	0.13	2.00	0.00	0.18	1.09
RestAM	-0.01	0.15	2.00	-0.01	0.23	2.63
RestOceani:	0.00	0.18	-3.74	0.00	0.26	-5.16
Mexico	-0.01	0.21	4.48	-0.02	0.29	5.79
RestEurope	0.03	0.21	3.42	0.04	0.32	4.61
RestAsia	-0.01	0.23	3.43	-0.02	0.32	4.53
Korea	0.00	0.25	-4.99	-0.01	0.36	-7.12

Numbers highlighted orange indicate lower exports compared to the baseline, numbers highlighted blue indicate higher exports compared to the baseline. The shading of both colours indicates the strength of the deviation to the baseline.

Source: GTAP database, Rabobank simulations

Table 2. Real GDP impacts % changes compared to baseline 2030

	CT100NL	CT100EU+	CT100ALL-	CT150NL	CT150EU+	CT150ALL-
Greece	0.01	-6.39	-1.39	0.01	-9.14	-2.77
Poland	-0.02	-4.21	1.01	-0.04	-5.90	0.83
CzechRep	-0.04	-4.08	2.53	-0.06	-5.70	2.86
Romania	-0.03	-2.64	4.04	-0.05	-3.86	4.89
Netherlands	-2.51	-2.60	2.86	-3.62	-3.77	3.31
Hungary	-0.02	-2.59	1.85	-0.03	-3.78	1.99
RestEU	-0.03	-2.54	2.36	-0.05	-3.71	2.63
Italy	-0.02	-2.49	2.13	-0.02	-3.61	2.40
Portugal	-0.02	-2.21	2.01	-0.03	-3.24	2.27
Finland	-0.01	-2.18	0.27	-0.02	-3.17	0.00
Germany	-0.01	-2.06	0.37	-0.02	-2.96	0.19
Belgium	-0.14	-1.84	2.53	-0.20	-2.73	2.93
Austria	-0.01	-1.67	1.65	-0.02	-2.43	1.87
Denmark	-0.01	-1.46	-0.05	-0.02	-2.09	-0.28
UK	-0.01	-1.41	1.10	-0.02	-2.08	1.18
Spain	-0.01	-1.34	1.70	-0.01	-1.98	1.99
Ireland	0.01	-1.26	2.55	0.01	-1.87	3.08
EFTA	-0.03	-1.26	0.90	-0.05	-1.81	0.99
France	0.00	-1.03	1.07	-0.01	-1.53	1.21
Sweden	-0.01	-0.72	1.46	-0.01	-1.07	1.78
Russia	-0.05	-0.47	1.83	-0.07	-0.65	2.33
ROW	-0.02	-0.13	2.50	-0.03	-0.17	3.24
SaudiArabia	-0.02	-0.10	2.09	-0.02	-0.14	2.74
Iran	-0.03	-0.07	3.59	-0.04	-0.11	4.63
Canada	-0.01	-0.01	-1.82	-0.01	-0.01	-2.85
RestAM	-0.02	0.01	2.61	-0.03	0.02	3.43
Indonesia	-0.02	0.02	3.28	-0.02	0.03	3.97
Australia	-0.01	0.02	-1.01	-0.01	0.03	-1.69
USA	0.00	0.03	-1.28	0.00	0.04	-1.85
Mexico	-0.02	0.07	3.80	-0.03	0.10	4.85
Brazil	-0.01	0.08	2.33	-0.01	0.11	3.06
SouthAfrica	-0.02	0.08	3.44	-0.03	0.12	4.53
RestOceania	-0.01	0.10	-0.49	-0.01	0.14	-1.11
CHG	-0.01	0.11	-5.52	-0.01	0.16	-7.65
RestAsia	-0.01	0.13	3.26	-0.02	0.17	4.28
RestEurope	0.00	0.15	2.74	0.00	0.21	3.64
India	0.00	0.16	2.26	0.00	0.23	3.01
Korea	-0.01	0.19	-1.24	-0.01	0.26	-2.17
Japan	0.00	0.23	0.38	-0.01	0.31	0.04
Turkey	-0.02	0.23	6.92	-0.03	0.32	9.19

Numbers highlighted orange indicate lower real GDP compared to the baseline, numbers highlighted blue indicate higher real GDP compared to the baseline. The shading of both colours indicates the strength of the deviation to the baseline.

Source: GTAP database, Rabobank simulations

Winners and losers

In the EU+ scenario Greece suffers by far the biggest economic impact from a carbon tax out of all EU+ regions. The GDP of the Greek economy is estimated to be more than 6% lower compared to the baseline if the EU+ implements a carbon tax of USD 100 (Table 2). Exports are estimated to be 20% lower compared to the baseline. Again, this is not entirely surprising given the fact that Greece has the most emission-intense economy in the

EU+ in the 2030 baseline (though Greece does score 'average' on the share of renewables in energy consumption).

While in Poland and the Czech Republic only 2-3 small sectors see a double-digit reduction in output compared to the baseline, in Greece the number of sectors is 10 and some are bigger in size compared to the total economy, namely water transportation (3% of total output in size; output reduces by 39% compared to the baseline) and petroleum & coal products (4% of total output; output declines by 20% compared to the baseline - probably linked to Greek refineries). On top of that, the coal extraction and other metals sectors, though small in size, see output fall compared to the baseline by a staggering 58% and 50%, respectively. Finally, a couple of large sectors also register a decline in output relative to the baseline, though less than for the sectors mentioned above: trade accounts for 7% of output and its output is 6% lower compared to the baseline in 2030, while private services (includes tourism) accounts for 21% of the economy and its output declines by 5% compared to the baseline. Against this background perhaps it was only logical that Greece proposed a carbon-price funded hedging mechanism to limit the impact of soaring fossil fuel prices on consumers and companies (see Bloomberg 2021) in September 2021.

Most EU countries are expected to gain from a broader carbon tax. Most EU+ countries see an increase in real GDP compared to the baseline in a scenario where the carbon tax is implemented outside the EU+ borders. The only exceptions are Denmark and Greece. In this scenario, not only would Greece's economy still be negatively impacted, it would also still be the third most heavily impacted economy in the world. Nevertheless, the impact on Greece is much less pronounced than under a tax regime that applies only to EU+ regions.

The sectoral perspective

From a sectoral perspective we see the usual suspects lining up for the highest impact, namely coal and natural gas extraction, electricity, air transportation, petroleum and coal products, chemicals, and water transportation. Often, these sectors see a double-digit decline of output (compared to the baseline) in the scenario where the tax is imposed on the EU+ region but not beyond. While for some sectors this double-digit decline of output is visible in most regions across the board in the EU+, for others the size of the impact is country-specific. While generally the coal sector is shrinking in size compared to the baseline, it is still a sector of relevance to the economies of Germany, Greece, Poland, Romania and the Czech Republic, (though the size is lower than 1% of output in all countries). Again, the natural gas sector sees substantial losses relative to the baseline, but is nonetheless relevant in Denmark, EFTA, and the UK. (For Hungary, the Netherlands and Romania, natural gas also plays a considerable role and the decline in output is just below 10% compared to the baseline). Big double-digit declines in output compared to the baseline are found in the chemicals sector in Greece, the Netherlands and Romania when a carbon tax is imposed on the EU+ region, while for EFTA, Sweden and Denmark the impact remains at less than 1% below the baseline. The decrease in output compared to the baseline of electricity and oil/petroleum products is particularly big in Greece. Water transportation impact is sizeable in Greece and Denmark. An outlier in the negative double-digit impact row is the other animal food sector in the Netherlands, which includes pork and poultry.

Some sectors in the EU will benefit, but these gains are small. The largest output increases are seen in electricity in Sweden (2% compared to the 2030 baseline in a USD 100 carbon tax scenario) and in EFTA (5% compared to the 2030 baseline in a USD 100 carbon tax scenario). This is likely a result of a combination of modelling dynamics and constraints: as mentioned before, the energy mix for electricity production in the model is relatively fixed to the structure of the base year (2014) as there is no explicit differentiation of electricity production based on renewables and fossil fuels. Substitution between technologies within the power sector is therefore strongly restricted. As a consequence, the power sector in countries which have a high share of fossil fuels in the base year suffer comparatively strong output reductions compared to the baseline, while the power sectors of countries with a high share of renewable technologies may even gain due to higher demand from other regions for electricity. In fact, in the simulation exports of the electricity sector increase by more than 20% (relative to the 2030 baseline) for these regions.

1.2.3 Impact at the global level

The macroeconomic perspective

Most economies outside of the EU+ region see lower GDP compared to the baseline upon the implementation of a carbon tax (Table 2). The only exception is Japan, which registers a slightly higher real GDP relative to the 2030 baseline in this scenario. China, and Canada are the countries that experience the largest impact on GDP from a carbon tax implemented in these major global economies in scenario 3. The impact on the Chinese economy stands out as it is much larger than on the other countries where a tax was imposed in scenario 3. The Chinese economy is expected to decline by 5.5% compared to the baseline. From a policy perspective this means that China's incentives to implement a carbon price of this magnitude will have to be driven by domestic reasons. For instance, the fact that the economic costs of no climate mitigation measures could be larger. The second vintage of NGFS scenarios indicates that this is the case at the global level (see Presentation on NGFS scenarios dated June 2021, p 37). The only graph revealing the impact on the Chinese economy concerns unemployment and it indicates that China is indeed worst off in a current policies scenario (no further mitigation).

Sensitivity analysis

Impact on the Chinese economy similar even if India also applies a carbon tax. We note that our major economies scenario does not include the third largest emitter in the world, India, which accounts for roughly 11% of global CO_2 fossil fuel combustion emissions. We excluded India because the country does not have a track record of ambitious climate change policy, though it did announce a net-zero target for 2070 at COP26. To see whether the impact on China would change if India joined the carbon taxation club, we did a sensitivity analysis by running an additional major economies scenario that also includes India. We see that in this scenario India becomes the economy that shrinks most (7% lower real GDP compared to the baseline), but we also see that the Chinese real GDP is still lower by almost 5% compared to the baseline in 2030 and that there is no significant change in the impact on other countries outside of the EU+ group. Hence, we note that from a real GDP-impact perspective India's participation does not affect the outcome of other countries, so they could decide to implement a carbon tax irrespective of India's participation.

Sensitivity analysis on the past impact of the EU ETS: We note that the relative economic impact could be influenced if the EU ETS pricing is also included in the simulations. To get an idea of how much the results could change we carried out a sensitivity analysis by applying a USD 150 carbon tax to the EU+ countries (who currently participate in the EU ETS, or, in the case of the UK, have an equivalent ETS) and a USD 100 carbon tax to the other major economies; the difference is roughly the average EU ETS prices over the year 2021. The results show that higher carbon taxation in the EU+ does not alter the results dramatically: the Chinese economy still sees lower GDP, roughly 5% compared to the baseline; the top 5 of countries suffering most economic damage remains the same; non-EU+ countries implementing a carbon tax witness an economic loss compared to the baseline; most EU+ countries benefit, though this time Poland, Germany and Finland experience a slight GDP decline compared to the baseline (<1%). The actual impact will be somewhere in between the scenario with a uniform carbon tax and the one with a higher tax for the EU+ countries since various sectors in the EU ETS system currently get the lion share of their allowances for free, so not all emissions are currently priced in. Moreover, the baseline projections rely on numbers that include the impact of the EU ETS as it was anticipated in 2019.

The sectoral dimension

Higher sectoral impacts are concentrated in a few energy-intense sectors. Double-digit declines in output compared to the baseline are concentrated in the coal, natural gas, electricity and transportation sectors. Output in other metals is also lower compared to the baseline with the biggest difference in Greece and Ireland, while chemicals sees the biggest negative difference compared to the baseline in China and rest of Oceania (New Zealand). Most sectors falling in this high-impact category are small in size compared to the country output, which is why the impact at the macro level is contained.

No sector is seeing a negative impact on output across the board. Most sectors see lower output relative to the baseline in some parts of the world and higher output in others. Even sectors with negative impacts on output in a higher number of countries, such as natural gas, show an output increase compared to the baseline in some countries such as Russia and Saudi Arabia (Note, however, that no carbon price is imposed on Russia and Saudi Arabia).

Winners

A more broadly applied carbon tax also benefits some economies. At the country level Turkey, Romania and Mexico are estimated to benefit most if a carbon tax is introduced beyond EU+ regions (i.e. EU+ and USA, China, Canada, Japan, Australia and Rest of Oceania). At the sectoral level it is energy-intense sectors that benefit – chemicals, other metals, ferrous metals, electricity - in countries that do not implement a carbon tax, such as Saudi Arabia. Interestingly, Romania and the EFTA see a double-digit increase compared to the baseline in the output of other metals and of electricity, respectively, even though they implement a carbon tax. The latter can be attributed to the fact that the energy mix in power generation of the EFTA regions is low in carbon intensity (i.e. high shares of renewables and nuclear).

1.2.4 The bigger picture

Although global economic pains are modest, that masks large impacts on some countries and even more so on particular sectors. World GDP is fairly unaffected by a CO_2 tax in all scenarios. However, there are countries that do register a sizeable negative impact on their economies compared to the baseline, especially when considering that the impact is structural in nature (affecting potential GDP, not just the economic growth in one year). The difference to the baseline in GDP of the Dutch economy in a Dutch and EU+ scenario is comparable in size to the contraction in GDP seen under the Great Financial Crisis (GFC) of 2007/8 (Erken et al, 2020). For the U.S. the impact (compared to the baseline) is smaller than during the GFC, but similar to the energy crisis (1974-1975) or the 80’s recession. For most countries the impact is smaller than the one seen during the economic turbulence triggered by the Covid-19 pandemic. China is one of the exceptions though. The country has weathered both the GFC (Erken, 2016) and the Covid-19 pandemic (Erken et al, 2020) without an economic contraction. A USD 100 CO_2 tax would however shave around 5% off its economy compared to the baseline and would do so structurally.

On top of aggregate country impacts, sectoral impacts are in some cases even more pronounced. As expected, country impacts do not capture the full impact of a carbon tax, which has both winners and losers at the sector level. As highlighted in the analysis above, there are quite some sectors that register a double-digit reduction of output compared to their output in the 2030 baseline. Outliers are coal in China and Greece which see output fall by 55% in a CT100ALL- scenario, compared to the 2030 baseline. Coal sees a fall in output of 40-50% compared to the 2030 baseline in several countries (Czech Republic, Romania, Poland) in both a CT100EU+ and a CT100ALL- scenario. Natural gas sees similar negative impacts in a few countries, as does other metals in Greece.

Model set up does not capture possible gains. The projected economic impacts are strongly negative as the model does not capture the mechanisms that could lead to economic gains. The simulation is important because, compared to existing studies, it brings a sectoral dimension that considers substitution effects and other trade and economic dynamics. However, there are limitations that bias the results towards capturing the negative effects. First, the model does not distinguish between fossil fuel and renewable production within sectors (in particular in the power sector) and thus cannot simulate substitution towards these technologies induced by the carbon tax. Hence, it does not allow for the economy to rebalance towards a larger renewables sector when renewables become cheaper. Secondly, the tax scenarios do not allow for endogenous technological change and hence do not capture the impact that a carbon tax is expected to have on inducing more innovation in low-carbon technologies. Thirdly, the model does not allow us to actively steer the expenditure of receipts from the carbon tax (see 1.1.4). The second vintage of NGFS scenarios (see Presentation on NGFS scenarios dated June 2021, p. 39) indicates that the economic impact of a net-zero scenario is very sensitive to the fiscal options. Choosing to recycle carbon tax receipts into government investment could actually lead to positive economic impacts of roughly 3% in 2030, compared to negative impacts of roughly 2.5% of GDP in the same year if the receipts were used for an employment tax cut or debt pay down. Finally, it should be noted that the most important gains – namely the gain of avoiding severe climate damage that come with no action – are not accounted for in the model simulation.

1.2.5 Comparison to other studies

There is a large, mostly theoretical, body of literature on the economic effects of carbon prices. We focus on publications which relate to the Dutch/EU context. It must be noted that comparability to our study is limited - among other things due to differences in study design, modelling frameworks, economic indicators analysed. Also, sectoral and regional foci or disaggregation levels, the magnitude of the carbon price shocks as well as the coverage of greenhouse gases differ. Nevertheless, since they all look at the impact of carbon taxes within the Netherlands it is interesting to roughly compare similarities and differences in outcomes.

Schotten et al. (2021) use an Input-Output model to analyse the impact of a EUR 50 /t carbon tax on (among others) production costs in the EU. (In comparison to CGE models, Input-Output models assume no price effects, thus substitution between products and production factors is not taken into account). They look at the impact of taxing all sectors and at the impact of taxing extended ETS sectors. In the extended ETS sector scenario, the carbon tax is applied to the manufacturing, energy and transportation sectors. As only the impact of taxing extended ETS sectors are shown in detail, results can be compared to this scenario only. Similar to what is observed in our study, they also find strong variations in impacts between countries and sectors. In the country breakdown of their results, it can be seen that Greece, the Czech Republic, Poland and Romania are also among the countries that experience comparatively strong impacts. Also, central eastern European (CEE) countries are generally hit harder than EU14 countries. However, while the impact on Greece is striking within the group of EU 14 countries in their study too, they find even stronger impacts on CEE countries (in particular, Bulgaria, Czech Republic and Poland).

Bollen et al. (2020) investigate the impact of a CO_2 tax of EUR 100 /tCO_2 and EUR 200 /tCO_2 on top of the EU ETS price using the CGE model WorldScan. They focus on the impacts in the Netherlands for the three most emission-intensive industry sectors (chemicals, oil and basic metal production). Aside from varying carbon tax levels, they also vary the way carbon tax revenues are re-used in the economy by either distributing them to households or passing them back to industry by means of targeted subsidies. Depending on these two scenario settings (carbon tax level and tax-revenue recycling mode), they estimate production losses of around 2-5% for these 3 industry sectors as a whole in 2030. The basic metals sector is hit hardest (up to 12% depending on the scenario settings) in terms of production losses compared to the other two sectors in all scenarios, followed by the chemical sector and oil products sector. In contrast to this, out of the three sectors our study finds the impact of a EUR 100 /tCO_2 carbon tax to be most severe on the chemical sector, followed by the petroleum products and then metal sector.

Hebbink et al. (2018) estimate how a carbon tax of EUR 50 (applying to all GHG emissions) imposed on the Dutch economy and on the whole of the EU, impacts sector-level sales prices. They first use a variable Input-Output model extended by substitution effects between production factors to calculate the price impacts of the tax. Moreover, they enrich the analysis by using elasticities for domestic and export demand to calculate the impact on sales in the Netherlands.

On the sector level, some results turn out similar, while for other sectors we find different results than Hebbink et al. (2018). Although a comparison to our study is hampered due to different aggregation of sectors, a rough comparison shows that they also find relatively strong negative impacts on sales in the chemical sector in the scenario where the carbon tax is introduced in the Netherlands only and in the scenario where the tax is introduced in the whole European Union. Moreover, they also see a somewhat less severe impact in this sector when the tax is imposed on the whole of the EU compared to introducing it in the Netherlands only. However, the impacts also differ compared to our study with respect to the results of other sectors. For example, they find negative impacts on the mining sector in the scenario where the tax is implemented only in the Netherlands, which changes to an increase in sales when the tax is introduced in the whole of the EU.

The impact on the overall Dutch economy is also less pronounced if the tax is introduced in the whole of the EU compared to introducing it only in the Netherlands. This is also different from our findings: the scenario where the tax is only imposed on the Netherlands shows very similar impacts for the Netherlands compared to the scenario where the tax is imposed on the whole of the EU. Among many differences to our study, Hebbink et al. (2018) used a model framework that does not account for second round (general equilibrium) effects. Thus, we expect that this difference to our study is due to using a CGE model which can take into account the decline in demand for Dutch exports from other (EU+) countries when the carbon tax is introduced there as well.

As part of the same study, Hebbink et al. (2018) also use a macroeconomic model to calculate the impact of a carbon tax imposed on the Dutch economy. They find that the impact on GDP is -0.9% - +0.5% depending on how the tax revenues are used in the model. In any of these scenarios this is less pronounced than what we calculated with the GTAP-E model in our study (i.e. -2.5% compared to the 2030 baseline in the scenario where the tax is imposed on the Netherlands only). Multiple differences between the modelling approaches and design of the research can account for this difference. Aside from our study's assumption of a carbon price almost twice as high as Hebbink et al. (2018), the fact that the energy mix in our model is relatively fixed to the 2014 base year (due to the lack of substitution to renewable technologies) can be a source for overestimation of impacts. On the other hand, our study does not cover all GHGs, which skews the impacts downwards compared to the study by Hebbink et al. (2018), which covers all greenhouse gas (GHG) emissions.

Bollen et al. (2019) use the general equilibrium model WorldScan to analyses the impact of different emission policy regimes for the Netherlands that all reach the same emission reduction in 2030 (46% compared to 1990 levels). The impacts of these different policy schemes are compared to a reference scenario which also reaches 46% emission reductions in 2030. They show the impact of each policy scheme on different sectors in the Netherlands as well as at the macroeconomic level. They find that the impact of a uniform CO_2 price leads to the most favourable welfare effects. Moreover, they show that recycling tax revenue via subsidies leads to better GDP results than recycling tax revenues as a lump sum payment to households.

1.3 Conclusions and recommendations

In this study we found that the impacts on Dutch real GDP are similar whether the CO_2 tax is introduced in the Netherlands only or in the whole of EU+ region. This is an important addition to the study by Hebbink et al. (2018). Thus, accounting for general equilibrium effects can be crucial to estimate the impacts of different carbon tax scenarios for countries that are highly interlinked by trade relations.

EU+ countries all experience negative impacts if the rest of the world does not follow. All EU+ regions see real GDP decline compared to the 2030 baseline if the tax is only introduced in this region (i.e. EU+ UK+ EFTA). At the top of the most impacted regions is Greece and the country with the least impact in this scenario is Sweden.

The Netherlands and most EU+ regions benefit from the introduction of a carbon tax in major economies beyond the EU+. However, this comes with mostly negative impacts on major economies outside the EU+ region that implement a carbon tax. Overall Dutch real GDP is higher compared to the baseline if a carbon tax is introduced beyond the borders of the EU+ region. In this scenario real GDP in most EU+ countries is actually higher than in the baseline. However, Greece is highly (negatively) impacted in both scenarios. Countries outside the EU+ that adopt a carbon tax stand to lose, with the exception of Japan. The Chinese economy witnesses the largest decline in real GDP compared to the baseline in such a scenario. But no mitigation is likely to have even higher costs and that is likely to be the driver of carbon pricing in China.

On the sector level, we see that impacts vary strongly depending on sector and scenario. Both in the EU+ and the broader carbon tax scenario we notice that emission-intense sectors such as natural gas and electricity are most negatively impacted in countries that adopt a tax, while in countries that do not adopt a tax it is also emission-intense sectors that gain in output compared to the baseline. Nevertheless, a gain is also found for the electricity sector in countries with a high share of renewable power (EFTA and Sweden) if the carbon tax is imposed on EU+ level only. If the carbon tax is introduced beyond the EU+, each EU+ region has some positive impacts in some sectors.

This study showed again that country-level impacts can mask large sectoral impacts and thus that it is important to also analyse these underlying sector-level changes. Overall, we note that the economic impact can be significant for some countries and sectors. However, the macro level does not reflect large impacts at the sector level as there can be offsetting effects on the sector or disaggregated regional level. Hence, it is important for financial institutions and policy makers to carefully consider the variety of impacts on the sector level. For financial institutions this reveals where the biggest risks (and opportunities) may lie. For policy makers this shows where the most vulnerable sectors are for which additional measures might be necessary to mitigate negative economic impacts (for instance, by directing tax revenues to push additional technology developments).

While any modelling exercises on this regional and sectoral scale are surrounded by limitations and uncertainties, they can be useful for the financial sector and policy makers to gain insights into possible impacts of carbon pricing. Nevertheless, it should be kept in mind that some of the limitations listed below may have skewed the outcomes upwards (e.g. no possibility to substitute away to renewable technologies; not steering the recycling of the carbon tax receipts, for example to use as subsidies in industry); other limitations listed may skew the outcomes downwards (e.g. not including all GHGs from all anthropogenic sources). To refine and enhance insights, additional research should be undertaken to addresses some of the limitations of this study, namely:

- Explicitly include current emission trading schemes. The interactions between ETS and carbon taxes are more complex to model, but this is possible and would bring the results closer to reality.
- Include all greenhouse gases. In this analysis we have only looked at the impact of taxing CO_2 from combustion of fossil fuels. The GTAP database does provide databases that include other GHGs. Taxing other GHGs (and thereby all industrial processes and emissions) would lead to more accurate estimates of the carbon tax impact. This is possible in the GTAP model, but the data and modelling tasks required went beyond the scope of this project.
- Simulate a gradual implementation. Since the GTAP model moves from one equilibrium to the other, it cannot be used to simulate a gradual transition nor does it capture short-term effects. The model can be adjusted to capture economic stickiness and allow for these dimensions to be estimated.
- Include possibility to substitute to renewables and endogenous (or exogenous) technological change. Such a feature would allow for higher carbon prices to push investments towards lower carbon technologies and would stimulate companies to invest in new, more efficient solutions. This could also translate to more economic benefits in some sectors.
- Steer the recycling of the carbon tax receipt. Being able to steer the fiscal receipt from carbon taxation can make a big difference for the economic impact, as also indicated by the second vintage of NGFS scenarios (NGFS scenarios presentation, page 39) and in the research by Bollen et al. (2019). Hence, it is important to include these options in future research.

2. A qualitative analysis of the impact of carbon pricing on the Dutch agriculture sector

Authors: Harry Smit and Stefan van Merrienboer (RaboResearch)

2.1 Introduction

This chapter gives a qualitative review of the impact of pricing GHG emissions on agriculture in the Netherlands and analyses the conditions under which such a pricing scheme could contribute to the goal of reducing the emissions. We start with a section on the data sources and the methodology used to close the large data gaps specific to the agriculture sector. Then, to illustrate the complexity of emission estimation in agriculture, we provide an overview of the main sources of GHG: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) per subsector. Next, we look at the relative emission intensities of various agricultural subsectors – a proxy for their vulnerability to an eventual carbon tax – and continue with an inventory of the possible on-farm mitigation solutions and an assessment of their potential impact and feasibility. We finish with the conclusion and a discussion of the results.

2.2 Methodology

Agriculture poses particular challenges to the estimation of emissions due to the heterogeneity of the subsectors and the diversity and complexity of processes that emit GHG. As a result, the estimation of GHG emissions is the result of complex models and is characterized by large data gaps and inconsistencies. For example, there is no global emission database covering all greenhouse gases and linked processes in agriculture.

For a deep dive into emissions in the Netherlands we consider the data provided by the Dutch Emission Authority (RIVM, emissieregistratie.nl) to be the most appropriate. However, this source is also characterized by two specific data gaps: 1) land use change is not reported and 2) the granularity is insufficient to assess vulnerability properly, as not all emissions are allocated to subsectors.

To improve the granularity, we developed a method to allocate sector GHG-emission data from Emissieregistratie.nl to agricultural subsectors based on data from Statistics Netherlands (CBS). We use agricultural statistics on land use, on premise energy use and animal numbers from CBS to allocate GHG emissions to subsectors. Table 3 gives an overview of the data sources used for the allocation. No GDP data could be found at this level of granularity either, but we have commissioned WEcR to provide this data. Due to limitations in data availability, the year 2017 was chosen as base year.

Table 3: Overview

Data source	Year	Description	Topic	Used to assign GHG emissions from:
CBS	2017	Agriculture; crops, livestock and land use by general farm type, region	Utilized agricultural area (UAA)	Land use related to farming practices, manure application, and synthetic fertilizer use
CBS	2017	Agriculture; crops, livestock, land use, and labour, national	Animal numbers (Livestock Units)	Enteric fermentation and manure use from young animals for fattening and bulls, and grassland renewal
WEcR	2017	Energy use and efficiency – Agriculture	Fossil fuels (Petajoule)	

Source: Rabobank

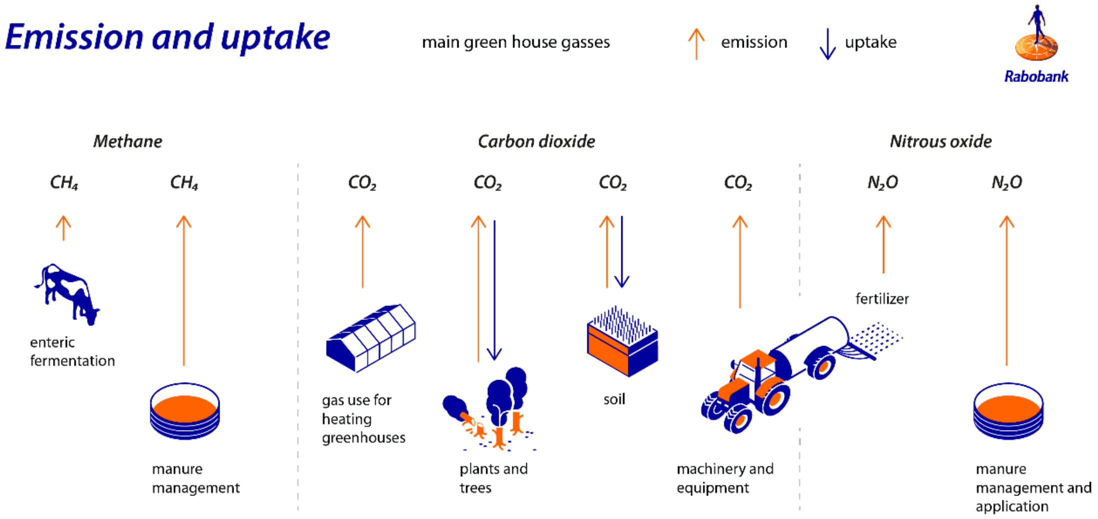
2.2.1 Overview of GHG-emission sources in Dutch primary agriculture

As indicated earlier, GHG emissions in agriculture are the result of various processes (see Figure 3). This section zooms in on the main emission drivers in Dutch agriculture.

Table 4 provides a deep dive into the distribution of emissions, both from a process and subsector perspective. The subsector with the highest GHG emissions is cattle farming, with 52.4% of total agricultural emissions. This sector is followed by greenhouse horticulture, which produced 28.8% of emissions, and pig farming which accounted for 8.1% of emissions These three sectors combined account for 89% of the GHG emissions in agriculture. The shares in emissions of other subsectors can be found in Table 4. From a process perspective, the main GHG-emission drivers are enteric fermentation (caused by the digestive system of farm animals) and manure storage and application. Another large source of GHG emissions is the use of fossil fuels for heating, electricity production and on-farm equipment. Taken together these activities emitted 79.2% of total GHG emissions in 2017. Overall in the Netherlands, 35% of GHG emissions in agriculture is caused by fossil fuel combustion, while 65% of GHG emissions is the result of biological processes inherent to agricultural production at the farm.

Estimating GHG caused by burning fossil fuels is relatively easy, as conversion factors of fossil fuel to CO_2 in combustion engines and heaters are well known. However, it is far more complex to estimate greenhouse gas emissions (such as CH_4 and N_2O) from biological processes because emissions vary greatly according to the circumstances under which these biological processes take place. For example, several of these processes occur in the open air under varying weather circumstances, while others take place in the animal’s rumen with a huge variety in feed use.

Figure 3: Processes in Dutch agriculture that release or uptake GHG emissions



Source: RaboReserach based on Intergovernmental Panel on Climate Change (IPCC), (2006). "IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Iventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). (IGES: Japan, 2006), 16

Table 4: Greenhouse gas emissions for Dutch agriculture (kt CO_2e, 2017)

Sector/Source	Natural gas use	Fossil fuel use by equipment	Manure application[1]	Synthetic fertilizer use	Enteric fermentation	Manure storage	Other[2]	**Total**	Total (%)
Arable farming	**0**	**285**	**374**	**445**	**0**	**0**	**423**	**1,528**	5.2%
Outdoor vegetable growing	**58**	**46**	**22**	**26**	**0**	**0**	**24**	**176**	0.6%
Tree nursery	**25**	**23**	**12**	**15**	**0**	**0**	**14**	**89**	0.3%
Bulb growing	**42**	**34**	**20**	**23**	**0**	**0**	**22**	**141**	0.5%
Fruit growing	**0**	**23**	**15**	**18**	**0**	**0**	**17**	**73**	0.2%
Champignon mushroom growing	**25**	**0**	**0**	**0**	**0**	**0**	**0**	**25**	0.1%
Greenhouse horticulture	**8,472**	**0**	**7**	**8**	**0**	**0**	**8**	**8,494**	28.8%
Vegetable growing	5,204	0	4	4	0	0	4	5,217	17.7%
Cut flower growing	1,879	0	1	2	0	0	2	1,883	6.4%
Pot plant growing	1,389	0	1	2	0	0	2	1,394	4.7%
Cattle farming	**81**	**568**	**906**	**1,055**	**7,768**	**2,401**	**2,677**	**15,457**	52.4%
Dairy farming	56	534	847	989	6,812	2,128	2,553	13,918	47.2%
Veal calf farming	25	34	2	0	663	213	0	936	3.2%
Other cattle farming	0	0	58	66	294	61	124	603	2.0%
Pig Farming	**83**	**34**	**0**	**0**	**465**	**1,798**	**0**	**2,380**	8.1%
Sow farming	25	10	0	0	140	629	0	804	2.7%
Pig fattening farming	59	24	0	0	326	1,168	0	1,576	5.3%
Poultry farming	**50**	**23**	**0**	**0**	**0**	**100**	**0**	**173**	0.6%
Laying hen farming	33	15	0	0	0	57	0	105	0.4%
Broiler farming	17	8	0	0	0	43	0	68	0.2%
Other livestock farming	**75**	**182**	**9**	**0**	**429**	**89**	**0**	**784**	2.7%
Fisheries	**0**	**175**	**0**	**0**	**0**	**0**	**0**	**175**	0.6%
Total	8,911	1,393	1,365	1,590	8,662	4,388	3,186	29,494	
Total (%)	30.2%	4.7%	4.6%	5.4%	29.4%	14.9%	10.8%		

Notes: 1) including GHG emissions from manure from cows in pastures. 2) GHG emissions from agricultural soils not related to manure application or inorganic fertilizer use (e.g. grassland renewal, crop residues).
Source: Emissieregistratie.nl, CBS, WEcR, Rabobank

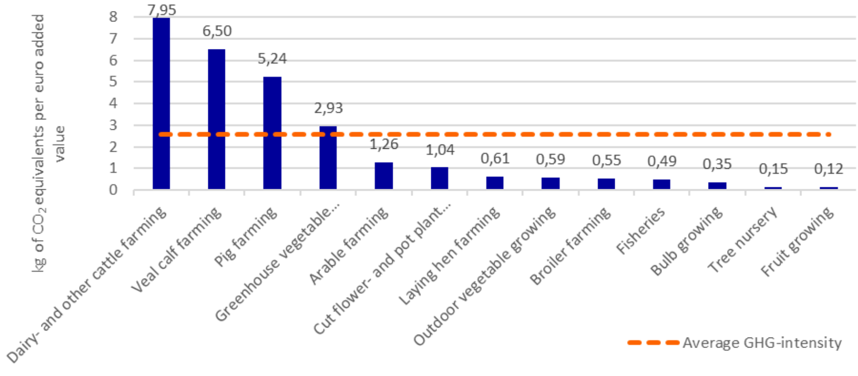
2.2.2 Greenhouse gas intensity of Dutch agriculture subsectors

Looking at absolute emissions only can be misleading if not corrected for sector size, as large sectors will logically emit more than smaller ones. Therefore, we also look at the emission intensity of sectors calculated as absolute GHG emissions (in kg CO_2e) divided by the value added (GDP) of each subsector. Figure 4 gives an insight into the GHG intensity per subsector for Dutch agriculture. The GHG-emission intensity varies widely within agriculture due to the very diverse set of activities and biological processes that take place in the various subsectors. The most emission- intense sector in Dutch agriculture in 2017 was dairy- and other cattle farming, at 7.95 kg CO2e/EUR. The intensity of this sector is significantly higher than the average intensity of 2.58 kg CO2e/EUR in agriculture. Other sectors with higher-than-average emission intensity are veal calf farming, pig farming, and greenhouse vegetable growing. The emissions caused by greenhouse horticulture relate for a significant part to gas use in electricity generators, while the heat produced by these generators is used for heating the greenhouse. Part of the emissions in greenhouse horticulture should therefore be allocated to electricity production. Due to the limited scope of this research, we did not take this into account in the calculations in this document. It is also important to note that the emission intensity within a sector can vary hugely, due, for example, to differences in technology, and differences in crops and their heating requirements in greenhouse horticulture.

Most emissions in the value chain are related to primary production where the value added is relatively low compared to the higher value added downstream. In some agricultural sectors primary production needs to take place in proximity to downstream activities (e.g. feed industry, milk processing, animal slaughter). Therefore those sectors cannot simply relocate their higher-emission intensity primary production to other countries. They would have to relocate the entire supply chain.

Dutch Agriculture has historically improved its emission performance in both absolute and relative terms, thereby decoupling economic growth from emissions. In 2017, GHG emissions in agriculture had declined by 15% since 1990, while agricultural output actually increased in the same period. As a result, GHG-emission intensity dropped in the past decades, mainly due to increasing resource efficiency (e.g. higher output per m^2 in greenhouses, higher milk yield per cow, faster growth of slaughter animals). In agriculture both efficiency and emission intensity vary from farmer to farmer. Top-down GHG-emission estimates like those we use here are not actually measured at farm level; they are estimated through complex models that make assumptions about emission factors per animal, per hectare, per unit of fossil fuel used, etc. Hence, we note that this data set provides no information on the emission intensity variance between farmers.

Figure 4: Greenhouse gas intensity per sector in Dutch primary agriculture, 2017



Source: Emissieregistratie.nl, CBS, WEcR, Rabobank

2.2.3 Potential solutions to mitigate GHG emissions

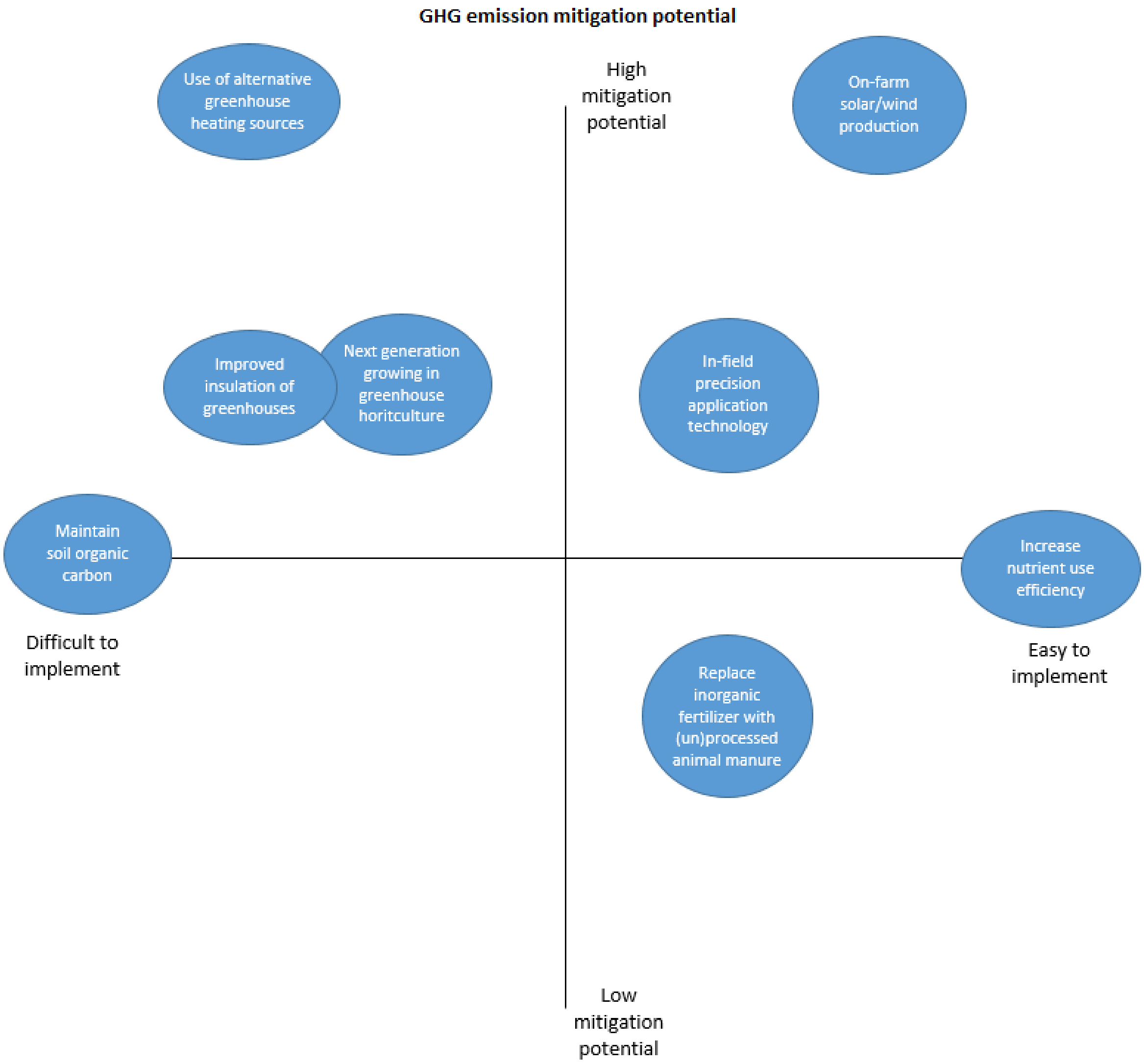
Having assessed the largest emitters and sources of emission in agriculture, we now look into potential mitigation solutions and focus on these main emitters. This section makes a distinction between potential GHG-mitigation solutions for crops (arable farming and horticulture) and livestock sectors. The reason for this split is the process differences that drive the GHG emissions in each sector. In crop sectors the use of natural gas, fertilizer and land farming practices are the main emission contributors. In livestock sectors the main emitters are enteric fermentation and manure management. The selection of solutions presented in this section is based on an assessment by agricultural experts of GHG-emission mitigation potential and ease of on-farm implementation.

Potential solutions for the crop sectors

In the crop sectors, there are alternative production methods available with lower GHG emissions. In crop farming the largest GHG-reduction potential lies in replacing the use of fossil fuels with renewable sources. The greenhouse horticulture sector is committed to a goal of becoming free from fossil fuel energy by 2040 by switching to geothermal energy and making use of residue heat from nearby industries. In theory, this switch in energy source has the potential to end fossil fuel use and its associated emissions for energy and heating. However, reducing GHG emissions linked to land- and fertilizer use to zero will be more difficult as these emissions are directly linked to microbial processes in the soil. Emissions from land- and fertilizer use could potentially be reduced by 44% in 2050, according to an explorative study by Wageningen UR (Vellinga et al. 2018).

Based on an assessment by agricultural experts the solutions are ranked by their ease of implementation, which often goes hand in hand with the impact on farm income (Figure 5). Some solutions can have a positive impact, for example, on-farm electricity production, increasing nutrient use efficiency, and precision application. GHG-mitigating solutions become less attractive from a farmer's perspective if they require capital investments with no direct financial benefit, or solutions that require a significant change in current farming practices. It should be noted that Figure 5 contains a simplification of reality and provides nothing more than rough guidance to compare mitigation solutions. The mitigation potential and the ease of implementation will vary hugely between companies, depending on their specific crops, animal species, buildings, machinery, soil, location, age of assets and many more factors.

Figure 5: Mitigation solutions for crops



Source: Wageningen Livestock Research (2018), Rabobank's own internal estimates 2021

Note: the size of the sphere does not relate to impact or size of the sector.

Potential solutions for the livestock sector

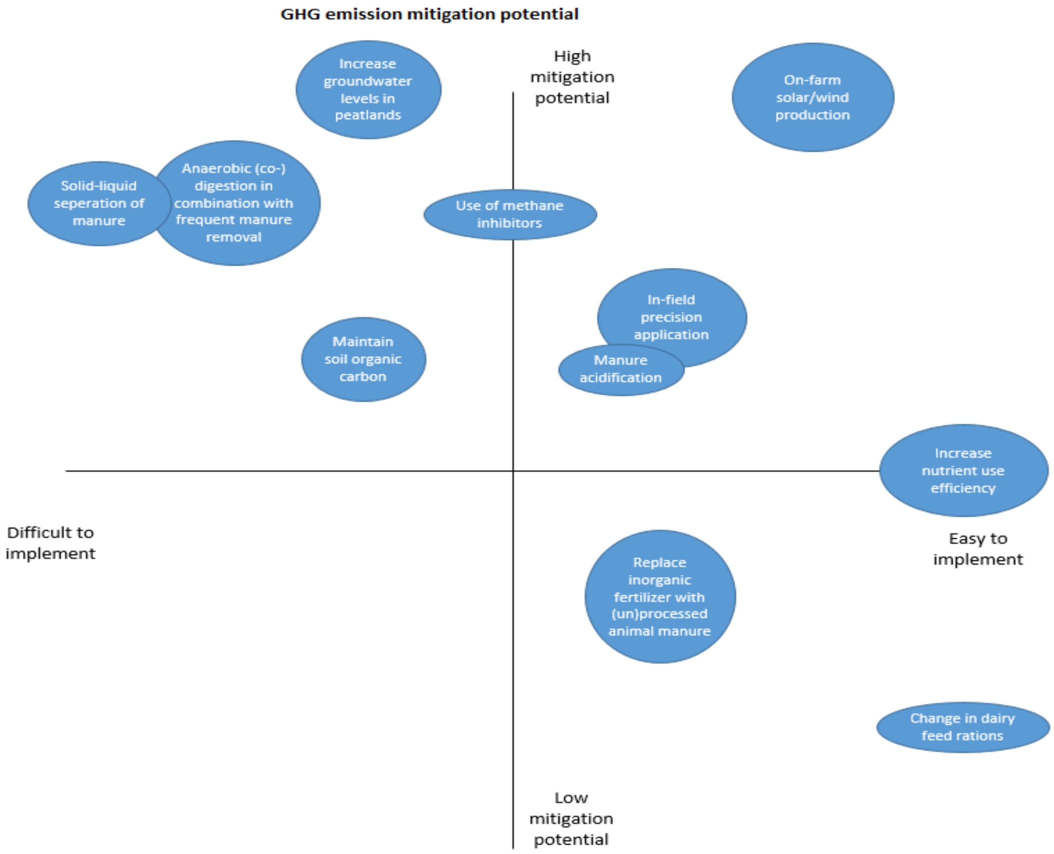
The explorative study referenced above also looked at reducing GHG emissions in livestock sectors. For the main emission-driving processes in livestock the estimated reduction potential is 50% for enteric fermentation and 75% for manure storage by 2050.

If negative externalities are not priced in, many solutions to reduce GHG emissions from cattle and pig farming will require significant capital investments and offer no direct financial benefit to the farmer. The current lack of financial incentive makes it difficult to implement these on-farm technologies. That may change if legislation becomes more restrictive in relation to GHG emissions, if a carbon tax is introduced or if carbon credits can be monetized.

Overall, it can be concluded that, for most farmers, there is no easy low-carbon alternative production system available to implement in order to reduce the negative income effect of a carbon tax. A carbon tax will therefore raise the cost price of agricultural products, only part of which can be compensated by switching to (more expensive) practices with lower emissions. The rise in cost price due to the carbon tax or the mitigating practice will have to be absorbed by off-takers. Otherwise farmers will face further margin pressure in an already challenging financial situation where farmer margins are close to zero.

We note that agriculture is also part of the solution for achieving a full transition to a net-zero economy, as it is one of the few sectors that can actually sequester GHGs. This is also inherent to farming and can be boosted by changes in farming practices (e.g. tillage practices).

Figure 6: Mitigation solutions for livestock



Source: Wageningen Livestock Research (2018), Rabobank 2021
Note: the size of the sphere does not relate to impact or size of the sector.

2.2.4 Impact of a carbon tax

The impact of a carbon tax is not only driven by the emission intensity analysed above, but also by the market power of the farmer. A price taker will not be in a position to pass on the costs further down the supply chain, while a price maker will. In this section we look into how trade dynamics can influence the impact of a carbon tax. Agricultural products can be grouped as follows:

1. Perishable products that are sold within an 800 km radius of the farm gate as fresh unprocessed produce (e.g. flowers, vegetables, ornamentals, soft fruit)
2. Perishable products that are processed into consumer products with short and longer shelf lives, where processing usually must take place within a 200-300 km radius of the farm gate (e.g. potatoes, sugar beets, milk, live animals)
3. Products that can be stored for longer and transported over longer distances (e.g. hard fruit (apples), flower bulbs, frozen meat and fish, wheat, milk powder)

Most agricultural products produced by farmers in the Netherlands are of average quality and compete on cost price with competing suppliers. Production costs at the farm make up the most important part of the cost price, next to logistical costs beyond the farm gate. Farmers compete with other farmers on two levels:

1. at farm gate level they encounter competition from competing farmers nearby (200-800 km see above)
2. at factory gate level of the processor (e.g. dairy processor, slaughterhouse) Dutch farmers compete with both EU and non-EU farmers via the market for processed products.

As a result, in most instances Dutch farmers are price takers. In a few instances the quality of the Dutch primary product is unique, in some instances because the Netherlands has a comparative advantage in producing them. Examples are flower bulbs, seed potatoes and horticultural seeds. In these markets Dutch producers are price setters.

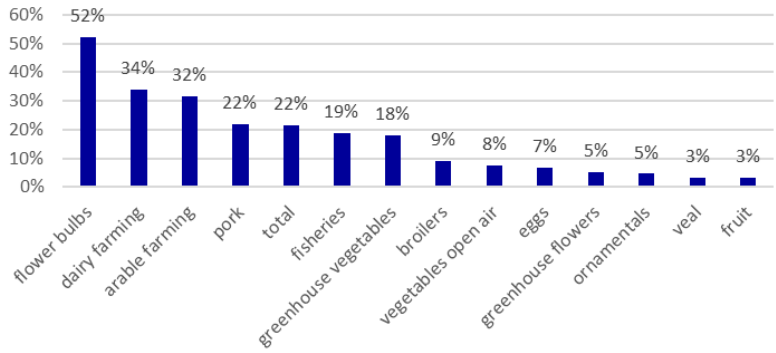
For almost every agricultural product produced in the Netherlands, Dutch farmers produce more than the domestic market can absorb. In general, about a third of Dutch agricultural production is sold in the Dutch market and two thirds is exported. Of all exports, some 80% is destined for the EU market while 20% is exported to non-EU countries.

In the absence of proper options to offset emissions to net zero, part of a carbon tax will have to be incorporated in the cost price, especially in the short term. To enable Dutch farmers to increase product prices after the introduction of a carbon tax, the carbon tax would also need to be applied to competing EU farmers. Since most Dutch farmers are price takers, a carbon tax for the Netherlands only would have to be absorbed entirely by Dutch farmers. They would not be able to pass on the costs to processors and/or consumers as their competitors would continue supplying the same products at the same price. A carbon tax for the EU market would raise cost prices of all EU farmers to the same degree, which would increase the ability of farmers to pass on the tax to EU processors and/or consumers.

As indicated earlier, several agricultural subsectors have a relatively high greenhouse gas intensity. A carbon tax of EUR 100 per tonne greenhouse gas emission (CO_2-equivalents) amounts to 75 percent and 50 percent of the added value per tonne greenhouse gas realized in dairy and pig farming respectively. Such a tax amounts to one third of the added value per tonne greenhouse gas in greenhouse vegetable growing and to around 10 percent of the added value per tonne greenhouse gas in greenhouse flower growing and arable farming. While in most other sectors such a carbon tax amounts to only 5 percent or less of the added value per tonne greenhouse gas.

The ability to raise product prices in the EU also depends on competition from outside the EU. Imports of agricultural products from outside the EU are regulated via a system of preferential tariff quota and – for most products prohibitive – import tariffs for imports outside these preferential quotas. Therefore, the threat of cheap imports replacing EU products is limited. For exports, however, the situation is different. EU products would become more expensive in export markets due to a carbon tax. Either buyers outside the EU would pay a higher price, which might be an option if carbon taxes were also applied to competing farmers in non-EU countries or in cases where the EU is the price setter (e.g. high-quality wines, specialty cheeses, horticultural seeds). But more often, EU exporters would have to absorb the carbon tax in order to remain price-competitive in export markets (e.g. pork carcasses, milk powder). Dutch dairy farmers, arable farmers and pork farmers are overly reliant on third countries for their sales (about one fifth to a quarter of total production). Therefore, these farmers would face most margin pressure following a carbon tax in the absence of a level playing field in relation to carbon taxes. In this respect, it is important that the EU ensures that mechanisms are in place to enable fair competition. The share of non-EU exports in total exports of Dutch agricultural products varies by subsector (Figure 7).

Figure 7: Share of non-EU exports in total Dutch agricultural exports (2020)



Source: WEcR

The Netherlands is by far the dominant supplier of flower bulbs worldwide and is a price setter. Therefore, the supply chain would be relatively well positioned to pass on a cost price increase following the introduction of a carbon tax to off-takers. And otherwise a carbon tax could be absorbed by flower bulb farmers given their relatively high added value per ton CO_2e. On the import side, Dutch farmers are reliant on imports of soybeans, corn and derived products (soy meal, corn gluten, etc.) as feed ingredients for which import tariffs are low or absent. These raw materials are imported by the feed industry and supplied to livestock farmers. Growing these crops is associated with deforestation, for example in Brazil. The EU may have to apply import tariffs on these products to include the GHG emission associated with growing these crops in non-EU countries. The envisaged Carbon Border Adjustment Mechanism seems to address this issue. For pork and poultry farmers, where purchased feed is the largest component of the cost price, this would put most pressure on margins. Dutch farmers would be more impacted than competing farmers in, for example, Denmark, Germany and France, because these farmers use more locally grown protein crops than imported soy.

Nitrogen fertilizer is an important input in crop and grass growing. The carbon footprint of fertilizer manufacturing is relatively high, ranging from 4 – 8 t CO_2e per tonne N (source: Yara company website). A tax of EUR

100/tonne CO2e corresponds to an increase of N-fertilizer product (e.g. Calcium Ammonium Nitrate) by around 50%. In other words, a carbon tax would make N-fertilizer products significantly more expensive. Import levies would be needed to prevent the replacement of European N-fertilizer by, for example, Russian-made N-fertilizer. An average application in soil-bound agriculture of about 100 kg N/ha corresponds to 0.6 tonne CO_2 equivalent per ha. A carbon tax of EUR 100/t CO_2e corresponds to EUR 60/ha or 3% of the average added value realised in soil-bound agriculture. This would impact margins of arable farmers most, as nitrogen fertilizer makes up a significant part of their cost price.

2.2.5 Discussion and conclusions

The idea behind applying carbon taxes is to make entrepreneurs pay for their carbon emissions. They can respond by changing to less GHG-intensive production methods/products. If producers cannot reduce their GHG emissions, the carbon tax will make those products more expensive and consumers will likely switch to alternative products with a lower GHG-emission intensity. In agriculture there are two factors that complicate these issues, but with the right policy actions, research and build-up of datasets these complications could be remedied.

Firstly, it is very complex to measure GHG emissions at individual farm level. The only way to estimate emissions is to apply standardized emission factors to agricultural processes. To lower GHG emission, farmers can, in theory, switch to practices with lower emission factors. However, in practice, as yet for many processes the methods to estimate the emission factors of various agricultural practices are neither consistent nor robust. Therefore, the measurement of GHG emissions for each process at the individual farm level will have to improve significantly before a carbon tax can steer farmers towards agronomic practices with lower GHG-emission intensities. This must be further developed and we strongly encourage such projects.

It is inevitable that most livestock production will continue to generate GHG emissions for some time to come: the only way to achieve more substantial reductions is if people lower their consumption of meat and dairy products and shift to more plant-based alternatives. That, however, requires an approach at a much larger, possibly global scale. If farmers in the Netherlands were the only ones to reduce their livestock production, farmers elsewhere would take over that production, very likely in less resource-efficient production systems, which would therefore increase GHG emissions at a global scale instead. In that case, a carbon tax might have the unintended effect of increasing emissions at the global level.

If farmers cannot avoid carbon taxes by switching to alternative farming practices or compensate the tax by raising the product price, carbon taxes will lead to further margin pressure for farmers. The agricultural subsectors, dairy, veal, pork and greenhouse vegetables have the highest greenhouse gas intensity. They also account for the largest share in total GHG emissions and would therefore be most at risk if a carbon tax was introduced. To avoid such a situation and create a level playing field, a collective approach is needed at an EU scale. Farmers, governments (with regulations, policies and targeted support measures), and private sector stakeholders that facilitate farmers in their adaptation need to work together to realize the goal of lower GHG emissions. Only then can a carbon tax help to facilitate the transition to net zero.

On a closing note, agriculture contributes to other important aspects of society as well, such as contributing to food security, having a lower impact on biodiversity than industry and, in some sectors, also sequestering carbon in the soil and in products. In some cases these factors can justify a certain level of GHG emissions if they are unavoidable. Moreover, a carbon tax on food could change relative price differences between foods and unintentionally steer consumers towards less healthy diets, as carbon emissions do not relate to the nutritiousness of food. Therefore, potential adverse side effects of a carbon tax need to be mitigated via other measures.

PART II: ON CARBON PRICING - CONTRIBUTIONS BY FINANCIAL INSTITUTIONS

1. Deep dive in the methods and data used for disclosure of emissions

Authors: Michael Kurz (PGGM), Han van der Hoorn (PGGM)

The analysis of the economic impact of climate-change mitigation policies requires high-quality data on GHG emissions caused by economic activity. We distinguish two levels of GHG-emissions data: national GHG inventory data and corporate GHG-emissions disclosure data. The former takes a macro perspective and describes total GHG emissions at the national level. The latter takes a micro perspective and describes GHG emissions of individual businesses. While both types of GHG-emissions data are indispensable tools for the evaluation of climate change mitigation policies, their usefulness depends on the quality of the data. Data is considered to be of high quality if it is verifiable, reliable, comparable, timely, and consistent (Hummel & Schlick, 2016).

1.1 National GHG inventory

There are two main approaches to GHG-emissions accounting: production-based accounting and consumption-based accounting. The Intergovernmental Panel on Climate Change (IPCC) defines production-based GHG emissions as emissions that are generated by domestic production. Consumption-based accounting of GHG emissions counts GHG emissions attributable to final domestic consumption, also taking imports and exports into account (Boitier, 2012). Even though most academic research recommends consumption-based accounting, the production-based approach to GHG-emissions accounting is currently adopted in policy and the methodology is well developed. The Paris Agreement requires countries to provide production-based data to the United Nations Framework Convention on Climate Change (UNFCCC).

GHG emissions at the national level are measured not directly but indirectly from fossil fuels used and other relevant industrial and agricultural processes taking a bottom-up approach. This requires a wide range of detailed economic activity data that is supplied by government departments, trade associations, and businesses. In most countries national statistics agencies compile the relevant data and estimate GHG emissions following the (IPCC, 2006) guidelines. They also monitor GHG emissions using mechanisms agreed under the obligations of the UNFCCC.

1.1.1 Three-tier methodology

A country can choose a method of GHG-emissions accounting from one of three tiers under IPCC guidelines. Each tier represents a different level of methodological sophistication to estimate GHG emissions (National Audit Office, 2008). Tier 1 methodologies rely on generic emissions factors that are multiplied by economic activity data. For example, under Tier 1 the emissions from the energy sector are simply estimated by combining the amounts of fuel combusted with a generic emissions factor. The generic emissions factor does not take the country-specific situation and level of technology into account. Therefore, this methodology requires only a low level of methodological sophistication and can be easily applied in any country. Tier 2 methodologies require the calculation of country-specific emissions factors, among other things. Tier 3 methodologies are the most complex and require bespoke modelling of emissions factors and economic activity data to estimate GHG emissions.

National GHG inventory data compiled using Tier 1 methodologies is the least accurate and precise, while national GHG inventory data complied using Tier 3 methodologies is the most accurate and precise. In other words, the data quality of national GHG inventories is a function of the general data quality of the economic activity data collected by national statistics agencies and the chosen methodology tier under IPCC guidelines. Generally, the

IPCC guidelines define data quality objectives regarding timeliness, consistency, completeness, comparability, accuracy, and transparency. In this sense the attributes of high-quality data as outlined in (Hummel & Schlick, 2016) are, in principle, engrained in the compilation process of national GHG inventory data.

Macroeconomic models used to analyse the economic impacts of climate-change mitigation policies heavily rely on national GHG inventory data. The insights that these models produce are therefore only as reliable as the data on which they are built. Governments should, therefore, further improve their methodologies to collect and model economic activity data and strive to use at least Tier 2 or 3 methodologies to estimate GHG emissions under the IPCC guidelines.

1.2 Corporate GHG-emissions disclosure data

While national GHG inventory data is essential for macroeconomic analysis, investors and businesses need to use corporate carbon-disclosure data to understand their own climate-change performance and exposure. An increasing number of businesses around the world now regularly disclose their own GHG emissions. The GHG Protocol from the Carbon Disclosure Project (CDP) could be described as the equivalent of the 2006 IPCC guidelines when it comes to corporate-level emissions reporting. It provides organizations with guidance of how to calculate their businesses' GHG emissions.

1.2.1 Tracking three types of emissions

The GHG Protocol recommends tracking three types of emissions: Scope 1 (Emissions generated directly by an organization), Scope 2 (Emissions of energy suppliers due to an organization's energy consumption), and Scope 3 (All other emissions along an organization's value chain, both upstream and downstream). The approach for the calculation of corporate GHG emissions is consistent with the idea of production-based accounting for national GHG inventories. However, it is important to realize that when estimating GHG emissions at the national level, statistical agencies do not aggregate GHG emissions disclosed by individual businesses. Instead they aggregate economic activity data to estimate national GHG emissions indirectly using methodologies prescribed under the IPCC guidelines. The typical recipients of corporate carbon- disclosure data are mainly investors, NGOs, policymakers, and regulatory agencies.

Data on corporate GHG emissions is often perceived by those stakeholders as being reliable and of high quality. The available guidance for corporate GHG-emissions accounting is not binding and disclosures are mostly voluntary. Comparison of disclosed corporate GHG emissions across different businesses has proved difficult because firms use different accounting methodologies and define reporting boundaries differently (Stanny, 2018). Moreover, many organizations do not have their reported emissions verified by independent third parties (Stanny, 2018). The lack of assurance of emissions data may allow mismeasured emissions to enter reports unnoticed. Smaller emitters in particular may lack the technical expertise and resources to implement proper measurement of GHG emissions and, therefore, rely on approximations and interpolations.

1.2.2 Technical and practical difficulties for most firms

Measuring and accounting for 100% of GHG emissions is technically and practically very difficult and costly for most firms and may not be feasible in some cases. The GHG Protocol therefore allows for accounting of potentially missing data in a 'Quantitative Statement of Completeness' which reporting firms can publish. However, as of 2016, less than 2% of businesses globally provided such a 'Quantitative Statement of Completeness'. These gaps in reporting have implications for the insights that can be drawn from corporate GHG emissions-disclosure data. According to Hummel & Schlick, (2016), sustainable firms tend to disclose timely and high-quality emissions data, while firms with poor sustainability performance tend to disguise their performance by releasing infrequent, low-quality reports. Therefore, the reliability of GHG emissions data is likely higher for 'green' firms.

Most investors do not collect GHG-emissions data directly from reports of individual businesses. Instead they use corporate GHG-emissions databases that are created and maintained by third-party data vendors – sometimes called data aggregators (Raynaud, Mary, Voisin, & Hazra, 2015). These third-party vendors generate comprehensive datasets by parsing individual businesses' public reports and other disclosure sources. If a business does not disclose GHG emissions, third-party providers tend to provide their own estimates of the firm's emissions, either derived from past disclosures or estimated using proprietary models. The sophistication of these models generally ranges from simple sector averages to complex input-output models of production processes. While the use of modelled data increases the coverage of GHG-emissions data, it also introduces significant inconsistencies in GHG-emissions data across vendors (Busch, Johnson, & Pioch, 2020). Additionally, the lack of sufficiently long time series of GHG emissions makes analysis difficult.

Generally, availability and consistency of Scope 1 emissions data is highest and businesses have the longest experience with reporting Scope 1 emissions compared to Scope 2 and 3. The calculation of Scope 2 and Scope 3 emissions is complex and presents unique challenges to businesses. The GHG Protocol has amended its GHG-emissions accounting guidance to provide additional guidance for the calculation of Scope 2 and 3 emissions. The amendments encompass 120 pages and 182 pages for Scope 2 and 3 emissions respectively, making each amendment longer than the original GHG-emissions accounting guidance.

1.2.3 Data consistency

Three important insights relating to consistency can be drawn from comparing corporate GHG- emissions data across third-party vendors: (i) Scope 1 and Scope 2 emissions data are more consistent than Scope 3 data, (ii) Consistency of the estimated GHG emissions from third-party vendors is lower than the GHG emissions directly reported by businesses. Additionally, consistency increases if Scope 1 and 2 emissions data are combined. (iii) Mandatory disclosure of GHG emissions does not substantially increase consistency of emissions data (Busch, Johnson, & Pioch, 2020). Current mandatory disclosure schemes in the USA and EU are based on facility-level data, which covers only between 33% and 49% of companies' Scope 1 emissions (Busch, Johnson, & Pioch, 2020). In other words, current mandatory disclosure data provides an incomplete picture of companies' total GHG emissions and needs to be supplemented by other data sources. Data vendors that provide estimated GHG-emissions data should increase the transparency of the modelling approaches used to impute missing data.

1.3 GHG emissions-disclosure data in financial institutions

An important application of corporate GHG-emissions disclosures is as an input for financial sector disclosures of emissions attributable to investment or loan portfolios. Unlike national GHG inventory data, the metrics disclosed by financial institutions are calculated by aggregating the Scope 1, 2, and/or 3 emissions across a portfolio. Current PCAF guidance recommends to only use Scope 1 and 2 emissions to calculate portfolio-level GHG-emissions metrics (PCAF, 2020). Aggregating Scope 3 emissions would lead to double counting if several portfolio companies in the same value chain reported Scope 3 emissions.

Two widely used metrics are the weighted average carbon intensity (WACI), which typically normalizes emissions by revenue, and the carbon footprint (CFP), which normalizes emissions by enterprise value (TCFD, 2017). The quality of the underlying corporate GHG-emissions data is critical to the accuracy and precision of these metrics. In other words, the metrics disclosed by financial institutions can only be as reliable as the corporate GHG disclosures that are used to compute them, and inconsistencies across data sources can significantly impact the results of empirical analysis.

Additionally, when comparing these metrics over time they tend to reflect changes in asset prices, exchange rates and inflation rates as well as actual changes in underlying GHG emissions. The accuracy of the use of enterprise value as a metric to normalize emissions is limited by the fact that the market capitalization part of the enterprise value is directly affected by fluctuations in the underlying asset prices (PCAF, 2020). In theory, increased production leads to increased emissions and raises asset prices and enterprise value. In practice, this correlation can be distorted or influenced by short-term factors. Similarly, the calculation of financed emissions can be impacted by exchange rate fluctuations when the largest currency in a portfolio and the currency used to denominate the financed emissions differ (Janssen, Dijk, & Duijm, 2021). Both of these examples can lead to fluctuations in the calculation of financed emissions that are not the result of actual changes in real-world emissions.

The ability to accurately compare financed emissions over time is a pre-requisite for steering on financed emissions. In order to circumvent the abovementioned effects, financial institutions could adjust for these effects when reporting common portfolio-level GHG-emissions metrics over time. However, the application of corrections highly influences the results and, if applied inconsistently, significantly reduces the comparability of results between different financial institutions. Iinitiatives like PCAF have offered financial institutions the tools to calculate financed emissions uniformly. Now similar tools to compare financed emissions over time are needed to advance disclosure and policy development.

2. The impact of carbon pricing on the energy transition

Author: Hans van Cleef (ABN AMRO)

A carbon tax was introduced by the Dutch government ahead of the Fit for 55 plans presented by the European Commission in July 2021. With the new climate targets set, and the European Commission's suggestions on how to implement these targets now under review, the EU as a whole is heading for a 55% carbon reduction in 2030. The European Commission has been using the European Union Emissions Trading System (EU ETS) as a pricing tool for carbon emissions within certain sectors since 2005. In its Fit for 55 plan, the Commission proposes a major revision of the EU ETS in order to meet the new targets. This research provides some insight from ABN AMRO's Group Economics into the effects of carbon pricing on the energy transition and asks: do companies falling under the EU ETS actually need a national carbon tax on top of the EU ETS?

2.1 EU ETS – A carbon reduction tool

The European Commission has been using the European Union Emissions Trading System (EU ETS) as the pricing tool for carbon emissions since 2005. With its Fit for 55 plan, the Commission has proposed a major revision of the EU ETS. Not only will the number of sectors falling under this trading scheme be expanded, but also the number of available emissions rights will be reduced at a faster pace. Currently, the EU ETS limits carbon emissions in the industry, electricity and aviation sectors (within the EU). This will be expanded to include the European maritime sector. On top of that, a separate ETS will be created for the buildings and road transport sectors.

Under the EU ETS cap-and-trade system no more emission rights will be available in 2050. As a result, by then all companies which fall under the EU ETS will need to have cut their emissions in such a manner that the overall EU result will be net zero. The current method of lowering the number of available emissions rights every year has proved successful over the past years. The sectors in scope have lowered their emissions by 25% since the start of the trading system. When the Fit for 55 proposal is approved, during the fourth phase (2021-2030) the cap on the number of available emissions rights will be lowered not by 2.2% each year but by 4.2%. This will lead to a 61% carbon reduction for these sectors by 2030, independently of what happens to EU ETS prices.

2.2 EU ETS – New record high prices

In the first half of 2021, EU ETS prices already rallied significantly ahead of the Fit for 55 proposal. Recently, prices have been pushed to new record highs above EUR 75/tonne, as high gas prices triggered worries regarding the upcoming winter season. As coal-fired power plants might have to step in when gas power plants cannot deliver enough, demand for these emissions rights will pick up. EUR 60/tonne is roughly what the Dutch authorities had in mind for the level of the Dutch carbon tax in 2024.

Market speculation is starting to play a bigger role in EU ETS pricing. The cap-and-trade system was initially meant to offer trading opportunities among companies. Currently, we are seeing increasing numbers of investors and speculators becoming interested in this instrument as a way to generate returns. Market speculation is only allowed for professional parties. Still, the interest in speculation on market price development increases every quarter. At the same time, the underlying number of available carbon permits will continue to decline every year, which will only serve to increase the risk of higher price volatility over time. That volatility can work both upwards and downwards for carbon prices. Poland and Denmark have already communicated their worries regarding price volatility to the European Commission. They would like to ban market speculation and have requested that EU

ETS trading be left to the companies in the sectors concerned. At the time of writing, the European Commission has not changed its policy.

2.3 European or national approach?

The question is: do companies falling under the EU ETS actually need a national carbon tax on top of the EU ETS? The idea of a national carbon tax is that it would stimulate a faster transition towards a carbon-neutral economy. Such a tax could indeed speed up the local energy transition but, at the same time, it could frustrate the working of the EU ETS. In the Netherlands, a carbon price was imposed with a starting level of EUR 30/tonne in 2021; this will be raised to EUR 125/tonne in 2030. Companies only have to pay the national tax if the ETS is trading below the price of the tax for that year. In other words, the national tax serves as a minimum if the ETS price is trading lower.

The aim of the EU ETS is to achieve carbon reduction at the lowest cost. This system allows easy and cheaper measures to be taken first. It therefore creates time for companies to find ways to reduce the more difficult and more expensive tonnes of carbon emissions at a later stage. The biggest results in the past few years have been seen in the utility sector, where replacing coal-fired power plants by wind farms is relatively easy to do at a cost. However, it is more difficult for heavy industry to find alternatives to lower carbon emissions, while trying to compete with companies who do not have to – or are unwilling to – take these kinds of measures (yet).

If a national tax is imposed, companies may be forced to speed up their transition at a higher cost, thereby losing competitiveness. This can be seen in countries that do a lot of international trade outside Europe. The European Commission has therefore also proposed a Carbon Border Adjustment Mechanism (CBAM) to counter some of these effects. However, it will be a few years before this CBAM is implemented and it will have only a limited scope at the start. But a national tax could also have a disturbing effect on the energy transition and broader climate policy: for instance, if a gas-fired power plant in country A was replaced by a less efficient coal-fired power plant in country B. After all, more emissions rights would then become available for industries outside the scope of the national tax, which would therefore delay the transition at the other locations.

2.4 Carbon tax can play an important role in ESR sectors

Does this mean that a national carbon tax can in fact play a role in the energy transition? We think it can. National authorities could add a form of carbon pricing for all sectors which are out of scope of the EU ETS or of the ETS for buildings and road transport that is now being created. The aim would be to trigger an acceleration of their carbon emissions reduction. These remaining sectors are all part of the Effort Sharing Regulation (ESR). The EU has raised its ambition for carbon emissions reductions in the ESR sectors from -30% to -40% in 2030. The Dutch Climate Agreement has set a -48% reduction target in 2030. Many of these ESR sectors (such as agriculture and waste management) are either less international in character or cannot be moved to other regions. As a result, national policies will be less affected by trends in other regions and will therefore achieve better results. Nevertheless, also within the ESR it could be wise for governments and sectors to cooperate with other countries to come to an aligned policy. Similar targets over a wider region may stimulate closer cooperation among companies within the same sector. This could speed up technological development and innovations.

2.5 A fragile balance between stimulating the energy transition or frustrating it

The idea of putting a price on carbon emissions is simple. It should act as a trigger to boost efforts to lower carbon emissions and to accelerate the energy transition. It should make alternatives that are available but not yet economical more attractive, or at least strengthen the economic case to invest. Nevertheless, there is a fragile balance between stimulating carbon reduction and frustrating this process. After all, putting a price on carbon emissions makes current processes more expensive. At the same time, research and development to boost innovation could be helpful. These two aspects are interconnected since companies in competition within the sector may struggle to absorb the initial losses of carbon emissions pricing while investing in the transition towards a new future. In the meantime, it will be difficult to switch from older – more carbon-intensive – techniques to carbon-neutral solutions if these solutions are not yet available. If demand for the older techniques does not drop and is not replaced by alternatives, these carbon prices have simply made the old production method more expensive.

There is also the matter of infrastructure to be considered. It will be a costly process to build a whole new infrastructure for techniques like green hydrogen or heat grids, as well as the expansion of the current electricity grid to meet future demand. The infrastructure will also take a long time to materialize, due not only to the technical burdens, but also to the legislative aspects and permits that must be arranged first. Examples are the construction of offshore wind farms or building/expanding a high-voltage electricity grid.

2.6 Carbon pricing must go hand in hand with stimulating new technologies

Carbon pricing could speed up the investments in the energy transition, but only to a certain level. As mentioned above, a higher price for carbon emissions will make the current processes more expensive and may even frustrate the energy transition as companies have less budget to invest. On top of that, if a fast-rising carbon price were to translate into higher consumer prices it would also result in upward inflationary pressure and reduced purchasing power. Whether a potentially rapid carbon price rise was triggered by market speculation or by overshooting a national carbon tax is of little relevance. The fact is that it would trigger unhelpful and possibly counterproductive side effects.

New technologies must be stimulated and demand for carbon-neutral alternatives must be supported. Otherwise the main effect of carbon pricing would just be to make the existing energy mix more expensive. Fit for 55 is therefore an important next step for EU ETS and a national tax could be helpful for ESR sectors. Still, it is difficult to achieve this energy transition without providing a way to induce commercial companies to invest in alternatives that are, as yet, unprofitable. After all, a tax controls the price/cost rather than supply. For non-ETS sectors, a tax does not ensure that you meet the target. Fortunately, there is a sense of urgency to make this transition to a carbon-neutral economy. But the financing of this transition needs to be carried on many shoulders. Carbon pricing is therefore only one half of the solution.

3. Return on Equity versus Return for Society

Author: Frans Wernekinck (de Volksbank)

In this chapter we describe how financial institutions can have a direct and positive effect on reducing GHG emissions and on halting biodiversity loss by shifting their view from simply looking at return on equity to a combination of return on equity and 'return for society'. This can be achieved by internalizing externalities in pricing and by ratcheting up the minimum sustainability conditions of their services that clients must adhere to.

3.1 Include GHG emissions in loan terms and conditions

Banks provide loans to clients for realizing projects and/or funding the balance sheet. When a company requires such a loan, they ask banks on what terms and conditions a loan could be possible. After comparing the different proposals, the company makes an agreement with the chosen bank and the loan is provided. While this implies a free market in which prices are competitive, it also provides opportunities for banks to make a targeted approach. For example: if 'bank A' offers a discount based on the positive impact on GHG the investee can make with the loan, it (ceteris paribus) may be able to offer a better price for that particular loan than its competitors and may stand a better chance of closing the deal. That said, providing a discount does cost money and therefore lowers the expected return on equity (ROE). This loss in ROE needs to be compensated somehow.

Since there is a competitive market, simply imposing a surcharge on polluting companies will not do the trick. Unless it is made mandatory by law, there is a good chance that other banks will not impose a surcharge and will therefore offer a better price for that loan. However, EU and global legislators are in fact considering obliging banks to apply a surcharge to clients for evidenced risks and will impose a penalty in the form of a direct capital surcharge to the financial institution or regulated entity should it fall short of this requirement. But for the moment, polluting companies will still receive a loan and 'bank A' may be left with a non-polluting loan it granted at a discount. This will then result in a given loss in the short run, which lowers the ROE and therefore costs 'bank A' and its shareholder(s) money.

3.2 Getting shareholders to embrace a broader concept of return

The mainstream neoclassical finance model is based on return on equity (ROE). This holds for shareholders, asset managers, pension funds and also for banks. Banks provide loans to companies and receive interest income and provisions in return. Companies use the loans to make investments and grow over time. Pension funds also invest large sums in companies for a long-term financial return. This is how the economy works.

However, at de Volksbank, we believe that the emphasis should shift from simply the return on equity to a combination of return on equity and 'return for society' (RFS).The concept of accepting a lower ROE in exchange for a positive RFS would first need to be embraced by shareholders if it is to work. Once this trade-off between money and a positive impact on GHG emissions is accepted, it will make it easier for 'green investments' to be funded and it will send a message to more GHG-intensive companies that better terms would be accessible if they were more climate-friendly. Which would accelerate the pace of change to a lower carbon economy.

If, in the long run, all banks embrace this return for society and add a surcharge for polluting loans (in one way or another), the discount provided and corresponding lower return will be compensated. The discount and surcharge can then be set in such a way that the shareholders' initial loss in ROE will disappear. It should also be noted that the pace and scope of new sustainability legislation and supervision standards will reinforce this process and force companies and financial intermediaries to price-in externalities to a greater extent.

3.3 Active engagement as an important tool

Although companies that improve their green credentials may gain access to better terms and conditions for loans, the road to becoming a greener company can be costly and engagement is necessary to make it happen.

The costs to become greener may outweigh any gains from a financial point of view. In order to start this change it certainly helps if the majority of the shareholders demand an increase in return for society and accept a lower return on equity, forcing the company to change its strategy to reduce carbon emissions. This active engagement can be an important tool to move to a greener economy. Financial institutions, like pension funds or banks, are the largest investors around and can therefore initiate this change. However, they will need to shift their perspective from simply investing an amount in a company and expecting a certain return to a more time-consuming but bigger role as a shareholder. This shift will also provide opportunities for financial institutions to promote this way of working to acquire new clients. In the end, it could have a positive impact on an institution's income (more new clients) and on the environment itself. Resulting in a win-win situation.

3.4 Biodiversity and the link with GHG emissions

The underlying goal of the Paris Agreement is to 'stop climate change in order to save the planet and its lifeforms'. Climate change affects not only humans but all lifeforms and ecosystems on earth. The rate and extent at which climate change currently occurs has detrimental effects on global biodiversity. Due to changing climates and changing precipitation patterns ecosystems are put under pressure, resulting in large scale extinction of those species that are unable to adapt to swiftly changing environments.

On top of this more indirect biodiversity loss due to climate change, a significant amount of nature is lost each year as a direct result of our own actions. Due to a growing and developing global human population, the need for ecosystem services has increased sharply in recent times. The growing demand for food security, energy supply, housing and consumer goods puts pressure on the way we use land. Natural areas are sourced for their raw materials and replaced by agricultural land. These land use changes not only result in decreased ecosystems, but the ecosystems themselves becomes less diverse and therefore less resilient to adapt to long-term or abrupt climatic changes. These changes in natural capital are currently not accounted for in climate disclosures and may thereby undermine the goal of the Paris Agreement.

Reducing greenhouse gas emissions will result in a decrease of the rate in which climate change occurs. This also results in more time for nature to adapt to the ecosystem changes, therefore reducing the negative effects on biodiversity of climate change. However, some ways of reducing greenhouse gases like 'bio burning power plants' have a large negative impact on biodiversity. Simply looking at reducing GHG emissions can therefore have a devastating effect on biodiversity which in turn would not lead to the desired outcome of the Paris Agreement. We need to do better than this, collectively as a financial sector and business community. We should ensure that GHG-reduction measures do not harm biodiversity and, in general, we should use broader concepts to give a value to natural capitals. Financial institutions should thus take into account a holistic environmental view when making investment decisions.

4. A bank's risk perspective on carbon taxing

Author: Guusje Delsing (Rabobank)

Carbon-emission pricing measures could have an impact on the financial system, either through lower corporate profitability, the devaluation of assets or through macroeconomic changes. In this chapter we look into the risk that the introduction of carbon pricing could pose to a financial institution/bank. Specifically, we consider a carbon-emission pricing mechanism, i.e., a carbon tax, which is applied to all greenhouse gases (GHGs). There are two components to analyzing the risk stemming from a carbon tax: 1) the vulnerability to the impact of such pricing, which we assess by looking at the emission intensity of sectors at a country level and 2) the likelihood that countries will implement policy, which we assess by looking at the stance of various countries and sectors towards carbon taxing in the short-to-medium term. The selection of sectors and countries included in this analysis reflects Rabobank's largest corporate exposures.

4.1 Definition of climate-change risk

Rabobank defines climate-change risk as the risk of any negative financial impact on the bank, stemming from the current or prospective impacts of climate change on its counterparties/clients. It is a driver of existing financial risk types, in particular credit risk, operational risk, market risk and liquidity risk. The Task Force on Climate-related Financial Disclosures (TCFD) also stresses the importance of assessing and disclosing climate-related risks to which banks are exposed. Furthermore, regulating authorities such as the ECB and EBA have increased their focus on this topic.

Climate change-related risks are commonly classified into two categories as also prescribed by the TCFD: physical risk and transition risk. Physical risk refers to the financial impact caused by the physical consequences of the actual change of climate. Transition risk is the financial impact caused by the transition to a low-carbon economy in anticipation of climate change. One of the triggers/drivers of transition risk is changing policy: the introduction/increase of a carbon-price mechanism is an example of such a policy change. In this chapter we will elaborate further on the financial risk of a carbon tax for banks and provide insights into the parts (sectors/countries) of the Rabobank portfolio which are most at risk. In particular we consider the short-term direct effect of a carbon tax on the profitability of counterparties.

In this chapter we focus on the "gross risk" of carbon taxing, i.e., the risk before any mitigation actions have taken place. Potential mitigation actions could reduce the risk of a carbon tax. This includes technological developments or the ability to pass on costs to clients or suppliers. Further elaboration on possible mitigation actions within the agriculture sector can be found in Part I, Chapter 2.

4.1.1 The vulnerability to a carbon tax

A carbon tax will have a direct financial impact on carbon-intensive companies and individuals. It will also have a second order effect on the macro-economy which will subsequently impact a bank's portfolio as well. The macroeconomic impact of carbon taxing was discussed in Part I of this report. In this chapter we focus on the direct financial impact, i.e., the additional costs of carbon taxing on sectors and companies and, as a result, the impact on their financial ratios and potentially on their profitability. In the following section we will further elaborate on the likelihood of carbon taxing for the different countries/regions and sectors.

A deterioration of the financial situation of clients may materialize as a risk for banks through the main financial risk types such as, but not limited to, credit risk or operational risk. For example, a decline in the profitability of clients leads to a deterioration in the client's credit quality, which results in an increased credit risk. Of the main risk types, we expect credit risk to be the most affected by climate change. This includes the risk of a counterparty losing a market to sell its products due to substitution caused by climate change transition risk.

To analyze the direct financial impact of transition risks like a carbon tax, we consider the carbon intensities at a sector and country level. We define the carbon intensity at sector level within a specific country as the sector's greenhouse gas emissions measured in CO_2 equivalents divided by the added value of a sector (in USD). A high carbon intensity will result in a relatively high vulnerability to transition risk in the broader sense, not only to a carbon tax. A carbon tax is one of the policy tools that can be implemented to steer the transition towards a low-carbon economy. A high carbon intensity will also translate to a high impact on the financial ratios of banks' counterparties in a carbon taxing scenario. The impact may be partially offset by mitigation options and the ability to pass on costs. As a result of the impact on the financial ratios, carbon taxing may materialize as a financial risk banks, e.g., credit risk.

Figure 8: Global carbon intensity classifications on sector level

Sectors	**Carbon Intensity**
Animal-Cattle	
Utilities-Generation and Distribution	
Animal-Dairy	
Other Utilities	
Water Transportation	
Remaining Transportation and Warehousing	
Other Animal (incl. Pig and Poultry)	
Crops	
Mining, Quarrying, and Oil and Gas Extraction	
Non-Food Manufacturing	
Animal-Aquaculture/Fishing	
Forestry and logging	
Food Manufacturing	
Public Administration	
Construction	
Services	
Trade	
Real Estate and Dwellings	
Finance and Insurance	

Source: GTAP, Rabobank

Notes: Red indicates a high emission intensity and green denotes a low emission intensity. Agricultural sectors are shown in italic. CO_2 emissions from industrial processes are excluded.

We compared carbon intensities across sectors (as well as countries). The results of this exercise for the sectors we defined are shown in Figure 8. The data used to construct this Figure comes from GTAP and has been aggregated to a global level, i.e., no country-specific effects are presented in this Figure. The emissions exclude those from land use and industrial processes (e.g., fossil fuels used as feedstock in plastics). As a result, the emission intensity of non-food manufacturing is likely underestimated. Not surprisingly, the generation and distribution of utilities, which includes fossil fuel combustion, can be seen to have a relatively high emission intensity compared to other sectors. Clients in the generation and distribution of utilities sector will therefore be prone to more transition risk from a bank's perspective than some of the other sectors. The agriculture sector as a whole also has some of the highest emission intensities. Given the relevance of the agriculture sector to Rabobank and the high heterogeneity within this sector, we have split it into 6 different subsectors. As Figure 8 shows, their emission intensities vary widely. For a more detailed analysis of the emission intensities for the agriculture sector in the Netherlands in particular we refer the reader to Part I, Chapter 2.

In addition to sectoral differences in emission intensities, there are also geographical differences. Each country has different emission intensities which reflect different practices (such as technology and regulation). These geographical differences are, in general, smaller than the sectoral differences. For the three highest intensity sectors, the European Union area has relatively low emission intensity compared to most other countries. Both regional and sectoral aspects should be considered when assessing the vulnerability of a portfolio to a carbon tax as a great variability can be observed in terms of the emission intensity and subsequently the financial impact.

4.1.2 The likelihood of carbon pricing

While the previous section elaborated on the impact that a potential increase in carbon prices might have, the financial risk of carbon taxing only materializes when and if the tax is actually implemented. To this end, we will now consider the scope and likelihood of such a carbon tax. Countries and sectors may differ in terms of their stance towards carbon taxing in the short- to medium- term.

To highlight some of the regional/country differences in terms of the likelihood of a carbon tax (or an increase thereof), we briefly mention the situation of the Netherlands, New Zealand, Australia & Brazil. Four countries in which Rabobank has a clear presence. In 2021 the Netherlands was one of the first countries in the EU to introduce a carbon tax for industry on top of the EU Emissions Trading System (ETS) as a means to achieve compatibility with the Paris Agreement. As further measures will be necessary to achieve the Netherlands' current emission reduction target, the carbon tax will be raised gradually up until 2030. New Zealand also has a carbon tax in place. While Australia was one of the first to adopt a carbon tax, this measure was only in place for a short time (until 2014). As it reduced emissions significantly, it is possible that a similar initiative may be introduced again in the future. Finally, Brazil has significant gaps in climate-change mitigation policymaking and carbon taxing seems an unlikely measure for the relative short term. In summary, carbon taxing shows a variability in likelihood of materializing across regions for the short- to medium- term.

Both the vulnerability of a carbon tax, i.e., the financial impact, and the likelihood of a carbon tax should be considered to obtain a full risk assessment. A high vulnerability and a low likelihood may still result in a low- to medium- risk assessment for a sector. In the longer term we expect more countries and sectors to adopt carbon taxation (or alternative mitigation policies with a similar effect) as the urgency to reduce emissions dramatically is likely to increase. Especially when more physical risk events manifest themselves.

Differences in the stance towards carbon prices can be observed not only at the country level, but also at the sector level. Some sectors are currently exempted from carbon taxing while others face stricter regulation, depending on the stance and view within a specific country. Implementation of carbon pricing mechanisms is now mainly focused on the manufacturing and energy sectors. Agricultural sectors are currently exempted from carbon taxing measures, with the exception of New Zealand which has announced that farmers may also be subject to additional carbon pricing as early as 2022. In the Netherlands, big industrial companies are subject to a carbon tax on top of the EU ETS (except for greenhouse horticulture and a few other sectors). Both regional and sectoral aspects should be considered when assessing the likelihood of a carbon tax as it is unlikely that a global carbon tax will be introduced.

4.2 Conclusion

Carbon pricing represents an explicit financial risk for banks, including Rabobank, due to its financial impact on businesses. This risk materializes through the main risk types such as credit risk. We have analyzed this financial risk by a combination of the likelihood of carbon taxing and the financial vulnerability to it represented by the emission intensity. Both the likelihood and vulnerability show a great variability over sectors as well as over countries/regions. On average the vulnerability differs more between sectors than between countries, whereas the likelihood of a carbon tax is often determined through national policies and regulations. The results of this exercise are part of Rabobank's climate change risk heatmap which will be used in the identification and measurement of climate change risk going forward.

We note that the transition risk is highest for sectors with high emission intensity located in countries where a carbon tax (or other transition policy) is most likely and substantial. As a result, transition risk measures such as carbon taxing will have the highest impact on these emission-intensive sectors.

We would also like to note that the impact of carbon pricing (and other mitigation measures) on businesses is not only a negative one. Just as with any transition, there are losers and winners. While the transition to a lower-carbon economy can present significant risks, it can also create big opportunities for businesses, banks and organizations that provide climate-friendly solutions. See for example (Rabobank, September 2020). Moreover, we note that failure to adopt mitigation measures in the short- to medium- term will increase the risk of a disruptive transition to a low-carbon economy in the longer term. From that perspective, a carbon pricing mechanism could be a good instrument to facilitate an orderly transition over time and thereby reduce the risk of an abrupt disruptive transition in the long run.

5. Carbon taxation and listed equity in a passively managed portfolio

Author: Robbert Lammers (MN)

5.1 Regulatory transition risks and listed equity

MN is the fiduciary manager of several large Dutch pension funds, including PMT, PME and Bpf Koopvaardij (Dutch Merchant Navy's Company Pension Fund) with over EUR 175 billion assets under management. For more than five years, MN has been working on the development of the climate policy for its clients. In 2019, all the work and knowledge developed over the past years was brought together in a comprehensive PMT and PME climate strategy PMT, PME, 2021).

This climate strategy distinguishes between transition risks and physical risks. Physical risks describe the direct negative effects that climate change can have on society and the economy, such as more frequent or more severe weather events like flooding, droughts and storms. Transition risks can occur when moving towards a less polluting, greener economy. Both physical and transition risks will occur simultaneously.

Four different transition risks are recognised: regulatory risks, technological risks, market risks and reputational risks. This research is focused on regulatory transition risk, i.e. the potential negative impact on certain businesses due to a change in laws and regulations directly linked to the transition towards a less carbon-intensive economy. The change in laws under consideration here is the introduction of a carbon tax.

The extent to which portfolios or asset classes are vulnerable to climate risks depends not only on the speed of transition and the underlying sector or regions, but also on the risk profile of the particular asset class. Based on the available research, MN made a broad assessment of estimates of which asset classes of the managed portfolios are most vulnerable to climate risks. This assessment shows that both the private equity and listed equity portfolios are vulnerable to climate risks, due to their risk profile and exposure to vulnerable sectors (Mercer, 2019, EIOPA, 2020). Suppose, for example, that a government imposes a carbon tax in certain high-carbon sectors. A listed equity portfolio with 50% exposure to these sectors will probably be more affected than a corporate bond portfolio with the same sector exposure. For an equity investor, the tax has a potential impact on future cash flows, which, generally speaking, will decline once the costs increase. The main issue for bond investors is whether the probability of default (PD) will increase during the remaining life of the bond. PD will increase significantly only if the extra expected costs are so high that the survival of a company is endangered. In this chapter the GTAP model - which was already applied to economic sectors in Part I, Chapter 1 - will now be used to explore the impact of different carbon tax scenarios on listed equity portfolios.

5.2 Broad, passively managed, listed equity portfolios

Almost all listed equity portfolios that MN manages for its clients are broad, passively managed, large- and mid-cap portfolios. This means that certain benchmarks are followed for a pre-set time period and no active investment decisions about individual companies are made. These benchmarks represent both developed and emerging markets and a large part of the free float-adjusted market capitalization in multiple countries. This method of investing is steadily gaining popularity with institutional investors like pension funds, especially in the Netherlands (Schoutsen, 2014, AFM, 2011).

Given that MN deems listed equities to be relatively susceptible to transition risks, and since the majority of the managed portfolios are managed passively, MN is interested in interpreting the results of the GTAP model (detailed in Part I of this report) with passively managed listed equity portfolios in mind. Considering the increasing popularity of investing in broad passively managed listed equity portfolios among institutional investors, MN believes this interpretation is also of value to other financial institutions and their stakeholders.

5.3 The GTAP model and a listed equity portfolio

In order to interpret the results in the context mentioned above, it is important to distinguish between using GTAP to:

A. model the effects of a carbon tax on production within a region, country or sector, as a result of rising costs
B. model the effects of a carbon tax on a broad, passively managed, mid- and large-cap listed equity portfolio

The modelling done for this research report focused on the scenario described at A. Any attempt to translate the GTAP model results from scenario A to results for scenario B must keep in mind that certain differences might distort the translation:

- The equity market ≠ the economy. Some (sub)sectors are over- or underrepresented within a passively managed listed equity portfolio, which could give rise to a certain tilt towards higher or lower carbon-intensity when comparing listed and non-listed companies within a sector.
- Decreased production does not necessarily mean lower equity value. A strong correlation is presumed. However, asset prices and production can be distorted or influenced by short-term factors that have nothing to do with the fundamentals or the structural relation between the two variables. Asset prices can, for example, react to market rumours.

Notwithstanding these caveats and the model limitations explained in Part I, this chapter tries to apply the results of the GTAP model to a broad listed equity portfolio. The aim is to identify certain expected vulnerabilities to a carbon tax within such a portfolio

5.3.1 Methodology

The results of the GTAP model show that sectors will be affected differently by a carbon tax. With the caveats mentioned above in mind, it can be expected that listed companies within certain sectors will experience similar effects to those modelled for the entire sector. The method of identifying vulnerabilities therefore starts with identifying the sectors most adversely affected by the carbon tax. Subsequently, we believe that the largest vulnerabilities for investors will be to companies within those sectors that are adversely affected and which, at the same time, comprise a relatively larger part of the total market capitalization of the different broad listed equity benchmarks.

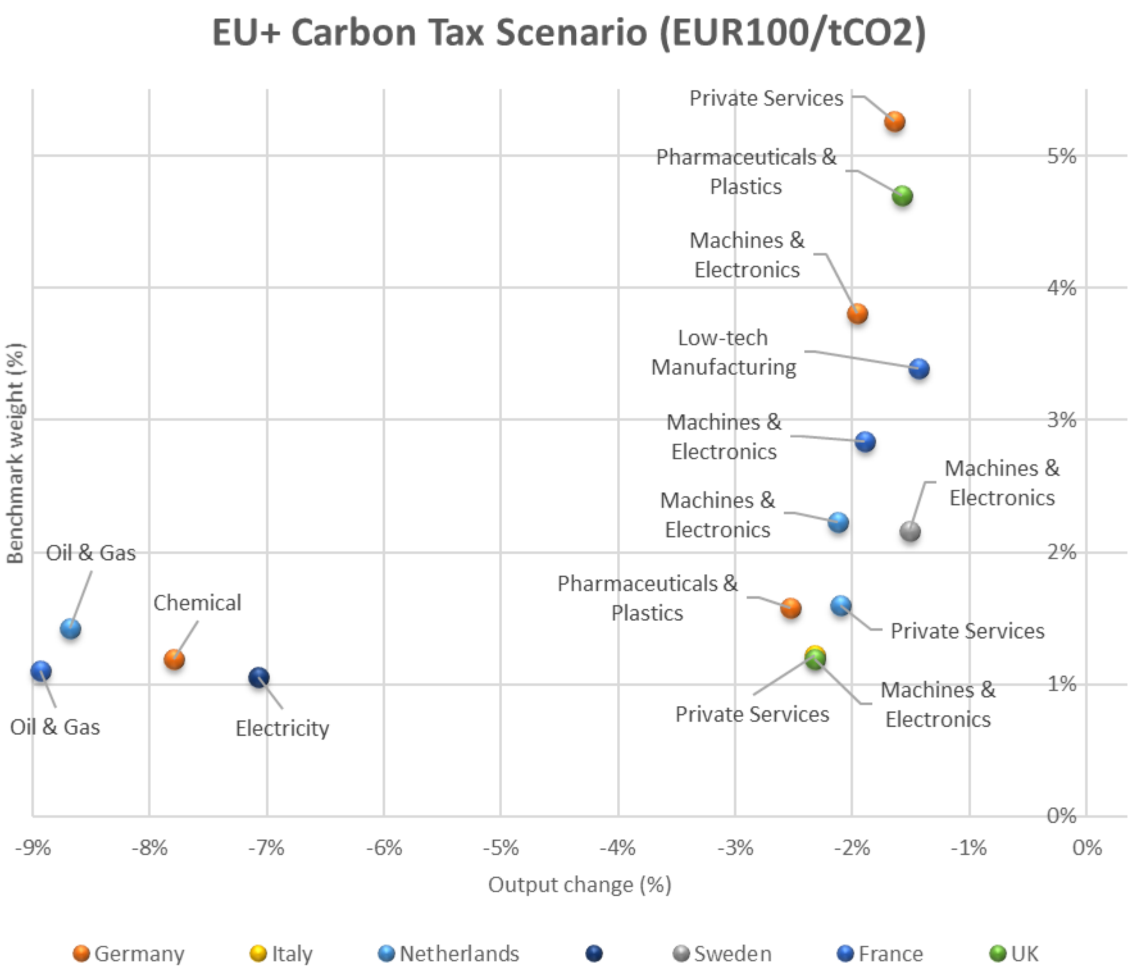
Because of regional differences the GTAP results are plotted against a broad global, European and emerging market listed equity benchmark. The presence of vulnerabilities within these benchmarks differs between the modelled scenarios. Given the limited space available in this report, we present only the most relevant results here.

5.3.2 Results

European carbon tax scenario

As mentioned in Part I, Chapter 1 of this report, a carbon tax introduced by the entire EU, EFTA and the UK would have little negative impact outside the EU economy. The model shows that the adverse effects of a European carbon tax of both EUR 100 and EUR 150 /t CO2 will, unsurprisingly, be felt predominantly within the European economies. The graph below shows the sectors that represent more than 1% of the total market cap of a broad European equity benchmark and that would simultaneously show more than a 1.5% decline in economic output according to the GTAP model. No sectors were identified that make up more than 1% of the total market cap that would show a significant increase in economic output according to the model.

Figure 9: Exposure of a broad European equity benchmark to the GTAP sectors (>1%), plotted against the modelled output change (%)

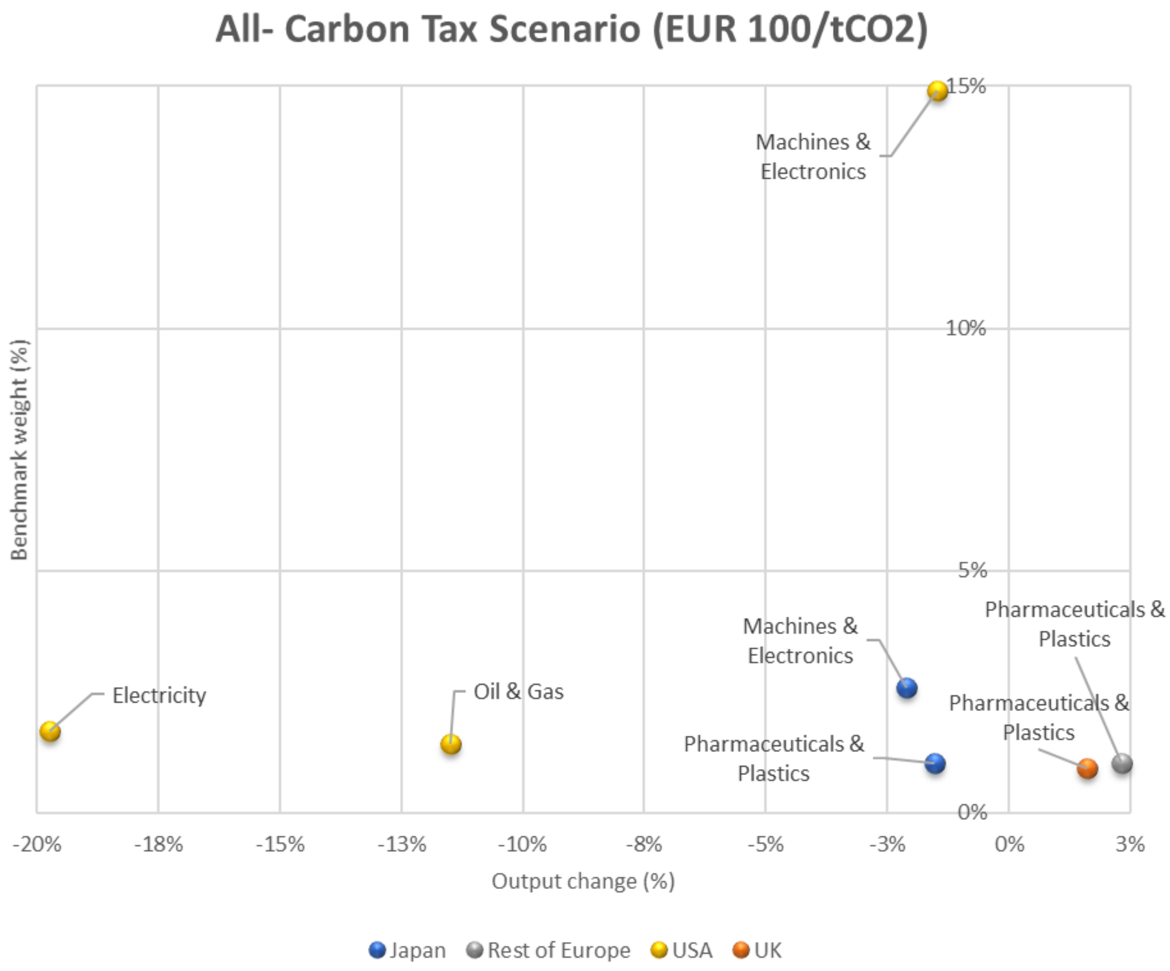


World carbon tax scenario

In a scenario where a carbon tax is implemented not only in European countries but also in countries such as the U.S., China, and Canada, our method identifies clear vulnerabilities for a broad global equity portfolio within sectors in the USA. The graph below suggests that the electricity, oil and gas sectors would be significant vulnerabilities within a broad global equity portfolio. According to the GTAP model the output of the U.S. electricity sector would decline by almost 20%. At the same time, the American oil and gas sector would see output decline by more than 11%. Together these sectors make up roughly 3.1% of a broad global equity benchmark.

The GTAP results imply that the pharmaceuticals & plastics sectors in both the UK and Rest of Europe would actually profit from a global carbon tax. This sector in these countries makes up around 2% of the global benchmark and shows an output increase of around 2% (UK 1.6%, Rest of Europe 2.3%).

Figure 10: Exposure of a broad global equity benchmark to the GTAP sectors (>1%), plotted against the modelled output change (%)

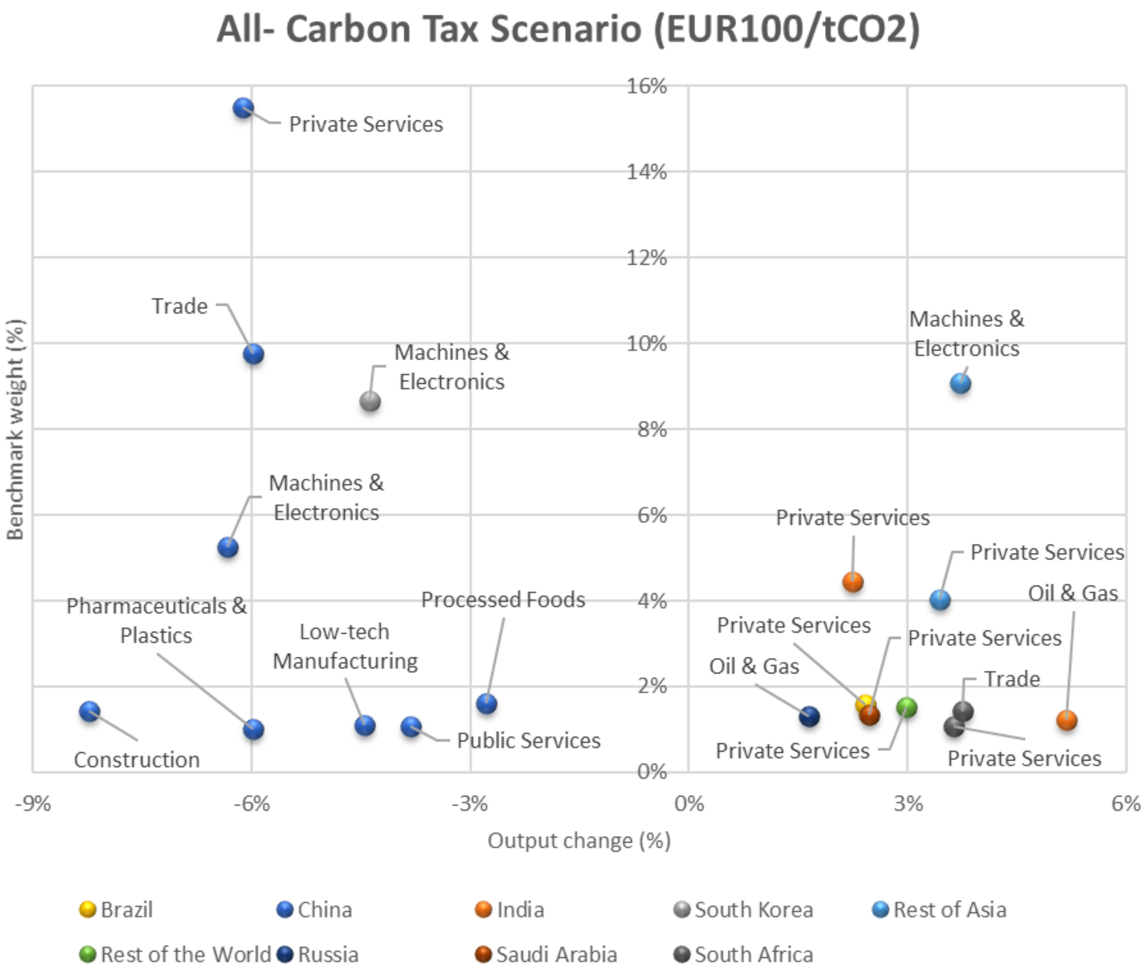


World carbon tax scenario – emerging markets

Whereas the scenarios discussed above show predominantly negative impacts on both global and European benchmarks, the effects of a global carbon tax on a broad emerging markets (EM) benchmark seems to be more ambivalent. Plotting the GTAP results on an EM benchmark clearly implies that vulnerabilities can be expected in Chinese equity. Specifically, the construction sector can expect a decline of more than 8% in economic output. The Private Services sector makes up a very significant part of the benchmark (almost 16%) and is modelled to see its economic output decline by more than 6%.

The declines in economic output of the Chinese Private Services and Machine & Electronics sectors contrast with increase output from these sectors in the Rest of Asia, suggesting that other Asian countries would profit from the Chinese decline. Both sectors make up more than 13% of the benchmark. The increase in economic output of the Oil & Gas sector in India is due to the fact that the scenario does not include a carbon tax in India.

Figure 11: Exposure of a broad emerging markets equity benchmark to the GTAP sectors (>1%), plotted against the modelled output change (%)



5.4 Conclusion

Mapping the GTAP results on broad passively managed equity benchmarks helps to identify possible vulnerabilities within portfolios that passively track these benchmarks. The research describes some clear vulnerabilities by identifying those sectors that both represent a significant part of the total market cap of a benchmark and show a significant modelled decline in economic output. These sectors are shown in the table on the right.

Scenario	Vulnerability
European carbon tax	Dutch and French Oil & Gas sector
	German Chemicals sector
	Spanish Electricity sector
Global carbon tax	U.S. Electricity and Oil & Gas sector
	Chinese Construction, Pharmaceuticals & Plastics, Machines & Electronics, Trade and Private Services sectors

For several years MN, and our clients, have chosen to construct our own benchmarks. MN constructs its own benchmarks based on a set of criteria that are formulated in investment strategies. The investment strategy includes all financial- and ESG-related criteria that apply for the construction of the benchmark. The investment strategies apply, on average, for a period of about three years, after which the strategy is evaluated and renewed. Climate risks and opportunities are therefore taken into account only when developing the investment strategy. This is an important difference compared to active investors, who also take climate risks into account in their investment decisions.

By identifying sectors that are highly exposed to climate risks and adjusting the benchmarks according to these findings, the overall climate risk exposure declines. Mapping the GTAP results to benchmarks or portfolios helps to identify high regulatory transition-risk exposure. It may serve as a guide for further research and ultimately aid the process of benchmark- and portfolio construction.

Conclusion

By Bouke de Vries (Rabobank)

Based on model calculations, this report has illustrated that carbon-emission pricing would affect regions and sectors to different degrees. Carbon-intensive sectors and those with a high portion of CO_2 intensive intermediate inputs will be particularly affected. The impact can be partially mitigated by substituting alternative low-carbon technologies like renewables. The calculations also signal that the negative impact of a CO_2 tax on Dutch GDP would be comparable whether the tax is introduced throughout the EU (including EFTA +UK) or only in the Netherlands. This is likely a result of second round effects in the modelling. If the CO_2 tax is additionally levied on large economies outside the EU+ region (including China, USA, Australia), the research indicates that macroeconomic outcomes could actually be favourable for the Netherlands as well as for most EU+ regions. This may be the effect of the lower carbon intensity of many EU+ regions compared to China or the US.

Specifically for Food & Agri, this research concluded that measuring and taxing GHG emissions at individual farm level is not yet feasible due to the variety and complexity of processes that cause greenhouse gas emissions in agriculture. At this time the only way is to apply standardized emission factors to agricultural processes and this will need to improve before businesses and financial institutions can steer optimally on reductions of emissions.

The report also discussed that financial institutions can play an important role in actively engaging with, encouraging and supporting their clients in the process of reducing emissions and promoting sustainability in a broader sense. The long-term appeal is that companies standing out in this respect can create growth opportunities. On the other hand, companies that do not take action pose a less attractive financing risk.

In all cases it is important to know what the performance and risks of a client actually are in regard to climate change and emissions, and to understand their economic impacts. This report takes another step towards gaining more insights.

Thank you for reading this report. If you have any feedback or questions, please send these to
Bouke.de.Vries@rabobank.nl, Sustainability Department of Rabobank, +31-6 109 69 623.

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7. Glossary

CBAM	Carbon Border Adjustment Mechanism
CDP	Carbon Disclosure Project
CEE	Central eastern European
CEPII	Centre d'Études Prospectives et d'Informations
CFP	Carbon footprint
CGE	Computable General Equilibrium
CO2	Carbon dioxide
CPB	Netherlands Bureau for Economic Policy Analysis
DNB	Dutch Central Bank
EBA	European Banking Authority
ECB	European Central Bank
EFTA	European Free Trade Association
EM	Emerging Markets
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
EU	European Union
EU ETS	EU Emissions Trading System
F&A	Food & Agriculture
GDP	Gross Domestic Product
GFC	Great Financial Crisis
GHG	Greenhouse Gas
GHGs	Greenhouse Gases
GTAP	Global Trade Analysis Project
IPCC	Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contributions
NEC	Not Elsewhere Classified
NGFS	Central Banks and Supervisors Network for Greening the Financial System
OECD	Organization for Economic Cooperation and Development
PCAF	Partnership for Carbon Accounting Financials
PD	Probability of default
PME	PME pensioenfonds
PMT	Pensioenfonds Metaal en Techniek
RFS	Return for Society
RIVM	Rijksinstituut voor Volksgezondheid en Milieu
ROE	Return on Equity
TCFD	Task Force on Climate-Related Financial Disclosures
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WACI	Weighted Average Carbon Intensity
WTO	World Trade Organization

8. TECHNICAL ADDENDUM

8.1 Appendix I. A brief introduction into the GTAP-E model

The GTAP-E model is a Computable General Equilibrium (CGE) model. CGE models were developed in the 1970s by applied trade economists. From the 1990s onwards, such models have been commonly used by international organisations, such as the World Bank, the UN, the WTO, the European Commission, and by large research institutes, such as the CEPII, to analyse the effects of taxes and tariffs on trade relations and on economic activity. CGE models are widely used to provide advice and assessments of economic policy. In agricultural, climate and energy economics they are a mainstream tool.

A CGE framework has three key features:

- The model describes economic activity and behaviour, i.e. demand, supply, trade, government and balancing identities;
- The underlying (global) database is balanced (clears out) and internally consistent, e.g. using multi-regional input-output tables;
- There is a set of parameters that drive responses of agents to any given perturbation or shock towards the initial equilibrium; these parameters can be trade elasticities, production function parameters or labour supply elasticities.

The standard GTAP model, where GTAP is an abbreviation from 'Global Trade Analysis Project', is such a CGE model. In addition to the economic equations and economic parameters, the centrepiece of GTAP is a worldwide database, so called input-output tables, in which bilateral trade patterns, production, consumption and intermediary demand of products, services and resources are described. The GTAP database differentiates between 65 economic sectors and 121 countries and regions.

Just like other CGEs, the GTAP model can be used to analyse the effects of taxes and tariffs. To that end, one first needs to estimate a baseline, i.e. a scenario of how the economy develops without the policies whose effect one wants to assess. Then one needs to shock the economy, i.e. introduce the policy change of interest. To assess the impact of this policy we look at the model outcome and focus the analysis on the percentage change of variables of interest, such as GDP or welfare, as a result of the policy shock compared to the baseline. The levels (nominal values) of these variables are not relevant for the scope of this analysis and cannot be interpreted as a precise prediction. It is the predicted percentage change in outcome variables which gives a decent indication of the effect of the shock.

In the standard GTAP model, energy substitution is not possible. The GTAP-E model, an alternative version of the standard model, in contrast, accounts for energy substitution. Furthermore, it accounts for CO_2 emissions from the combustion of fossil fuels, which is essential for our analysis. This framework makes it possible for us assess the impact of the energy transition, which is the focus of this study.

Unfortunately, the GTAP-E model also knows some limitations. It does not directly account for non-CO_2 emissions and process related CO_2 emissions. (There are special versions that do include these emissions, but time and resources constraints did not make it possible to include them in this analysis). GTAP-E also does not allow us to model specific ways in which the government could recycle the carbon tax income nor does it allow for modelling a gradual introduction of a carbon tax.

8.2 Appendix II: Technical specifications model

8.2.1 Geographical aggregation

The geographical aggregation reflects the regions of interest to the Working Group on Carbon Pricing members. We separated the biggest European countries, North American countries and the biggest emitters. According to the EDGAR - Emissions Database for Global Atmospheric Research, the following countries in Table AII.1 are the biggest CO_2 emitters:

Table AII.1: Top 20 most emitting countries according to EDGAR - Emissions Database for Global Atmospheric Research

Rank	Country	CO_2 emissions (total, in $GtCO_2$)
1	China	11.30
2	USA	5.28
3	India	2.62
4	Russia	1.75
5	Japan	1.20
6	Germany	0.75
7	Iran	0.73
8	Korea	0.70
9	Saudi Arabia	0.63
10	Canada	0.59
11	Indonesia	0.56
12	Brazil	0.50
13	Mexico	0.50
14	South Africa	0.48
15	Turkey	0.42
16	Australia	0.42
17	United Kingdom	0.37
18	Italy	0.34
19	Poland	0.33
20	France	0.32

Source: https://edgar.jrc.ec.europa.eu/

The final country aggregation looks as follows (using GTAP regions and codes):

Number	Code	Aggregation	Description
1	AUS	**Australia**	Australia
2	NZL	**RestOceania**	New Zealand
	XOC		Rest of Oceania
3	CHN	**CHG**	China
	HKG		Hong Kong, Special Administrative Region of China
4	JPN	**Japan**	Japan
5	KOR	**Korea**	Korea, Republic of
6	IND	**India**	India
7	IDN	**Indonesia**	Indonesia
8	BRN	**RestAsia**	Brunei Darussalam
	KHM		Cambodia
	LAO		Lao PDR
	MYS		Malaysia
	PHL		Philippines
	SGP		Singapore
	THA		Thailand
	VNM		Vietnam
	XSE		Rest of Southeast Asia - Myanmar - Timor-Leste
	MNG		Mongolia
	TWN		Taiwan
	XEA		Rest of East Asia - Korea, Democratic People's Republic of - Macao, Special Administrative Region of China
	BGD		Bangladesh
	NPL		Nepal
	PAK		Pakistan
	LKA		Sri Lanka
	XSA		Rest of South Asia - Afghanistan - Bhutan - Maldives
	KAZ		Kazakhstan
	KGZ		Kyrgyztan
	TJK		Tajikistan
	XSU		Rest of Former Soviet Union - Turkmenistan - Uzbekistan
	ARM		Armenia
	AZE		Azerbaijan
	GEO		Georgia
9	CAN	**Canada**	Canada
10	USA	**USA**	United States of America
11	MEX	**Mexico**	Mexico
12	BRA	**Brazil**	Brazil
13	ARG	**RestAM**	Argentina
	XNA		Rest of North America

	BOL		Bolivia
	CHL		Chile
	COL		Colombia
	ECU		Ecuador
	PRY		Paraguay
	PER		Peru
	URY		Uruguay
	VEN		Venezuela (Bolivarian Republic of)
	XSM		Rest of South America - Falkland Islands (Malvinas) - French Guiana - Guyana - South Georgia and the South Sandwich Islands - Suriname
	CRI		Costa Rica
	GTM		Guatemala
	HND		Honduras
	NIC		Nicaragua
	PAN		Panama
	SLV		El Salvador
	XCA		Rest of Central America
	DOM		Dominican Republic
	JAM		Jamaica
	PRI		Puerto Rico
	TTO		Trinidad and Tobago
	XCB		Rest of Caribbean
14	AUT	**Austria**	Austria
15	BEL	**Belgium**	Belgium
16	CZE	**Czech Republic**	Czech Republic
17	DNK	**Denmark**	Denmark
18	FIN	**Finland**	Finland
19	FRA	**France**	France
20	DEU	**Germany**	Germany
21	GRC	**Greece**	Greece
22	HUN	**Hungary**	Hungary
23	IRL	**Ireland**	Ireland
24	ITA	**Italy**	Italy
25	NLD	**Netherlands**	Netherlands
26	POL	**Poland**	Poland
27	PRT	**Portugal**	Portugal
28	ROU	**Romania**	Romania
29	ESP	**Spain**	Spain
30	SWE	**Sweden**	Sweden
31	BGR	**RestEU**	Bulgaria
	HRV		Croatia
	CYP		Cyprus
	EST		Estonia
	LVA		Latvia
	LTU		Lithuania
	LUX		Luxemburg
	MLT		Malta
	SVK		Slovakia

	SVN		Slovenia
32	NOR CHE XEF	**EFTA**	Norway Switzerland Rest of European Free Trade Association - Iceland - Liechtenstein
33	GBR	**United Kingdom**	United Kingdom
34	RUS	**Russia**	Russian Federation
35	ALB BLR UKR XEE XER	**RestofEurope**	Albania (ALB) Belarus (BLR) Ukraine Rest of Eastern Europe (XEE) - Moldova Rest of Europe (XER) - Andorra - Bosnia and Herzegovina - Faroe Islands - Gibraltar - Guernsey - Holy See (Vatican City State) - Isle of Man - Jersey - Monaco - Montenegro - North Macedonia - San Marino - Serbia
36	IRN	**Iran**	Islamic Republic of Iran
37	TUR	**Turkey**	Turkey
38	SAU	**Saudi Arabia**	Saudi Arabia
39	ZAF	**South Africa**	South Africa
40	BHR ISR JOR KWT OMN QAT TUR ARE XWS EGY MAR TUN XNF BEN BFA CMR CIV GHA GIN NGA SEN TGO	**RoW**	Bahrain Israel Jordan Kuwait Oman Qatar United Arab Emirates Rest of Western Asia - Iraq - Lebanon - Palestinian Territory, Occupied - Syrian Arab Republic (Syria) - Yemen Egypt Morocco Tunisia Rest of North Africa - Algeria - Libya - Western Sahara Benin Burkina Faso

	XWF		Cameroon
	XCF		Côte d'Ivoire
	XAC		Ghana
	ETH		Guinea
	KEN		Nigeria
	MDG		Senegal
	MWI		Togo
	MUS		Rest of Western Africa
	MOZ		Rest of Central Africa
	RWA		South Central Africa
	TZA		Ethiopia
	UGA		Kenya
	ZMB		Madagascar
	ZWE		Malawi
	XEC		Mauritius
	BWA		Mozambique
	NAM		Rwanda
	XSC		Tanzania, United Republic of
	XTW		Uganda
			Zambia
			Zimbabwe
			Rest of Eastern Africa - Burundi - Comoros - Djibouti - Eritrea - Mayotte - Seychelles - Somalia - Sudan
			Botswana
			Namibia
			Rest of South African Customs Union - Eswatini - Lesotho
			Rest of the World - Antarctica- Bouvet Island - British Indian Ocean Territory - French Southern Territories

8.2.2 Sectoral aggregation

For the sectoral aggregation we looked to single out the most polluting sectors and the sectors of interest to the working group, similarly to the geographical aggregation.

The top-15 most polluting sectors in GTAP-E are:

Number	Sector description	Sector code	Mtons CO_2 in 2014
1	Electricity	46 ely	12637
2	Transport nec	52 otp	3253
3	Mineral products nec	36 nmm	1346
4	Air transport	54 atp	1271
5	Ferrous metals	37 i_s	1133
6	Petroleum, coal products	32 p_c	863
7	Chemical products	33 chm	854
8	Water transport	53 wtp	565
9	Gas manufacture, distribution	47 gdt	283.7
10	oil	16 oil	282.1
11	gas	17 gas	187.8
12	construction	49 cns	175.7
13	Paper products publishing	31 ppp	174
14	Metals nec	38 nfm	171.2
15	Trade	50 trd	163.3

Source: GTAP-E database, 2014

Agricultural sector aggregation
Based on Part I Chapter 2 we suggest the following aggregation in order to separate the large emitters in Dutch agriculture.

Number	Code	Description	Aggregation name
1	**v_f**	Vegetables, fruit, nuts	VegFruits
2	**pdr**	Paddy rice	OtherPlants / Grains, seeds, crops
	wht	Wheat	
	gro	Cereal grains nec	
	osd	Oil seeds	
	c_b	Sugar cane, sugar beet	
	pfb	Plant-based fibers	
	ocr	Crops nec	
3	**ctl**	Bovine cattle, sheep and goats, horses	Cattle
	rmk	Raw milk	
4	**oap**	Animal products nec	OtherAnimalF / Other Animal Food
	wol	Wool, silk-worm cocoons	
5	**frs**	Forestry	Forestry & fishing
	fsh	Fishing	

Processed foods
We compile all processed food in one sector.

Number	Code	Description	Aggregation
6	**cmt**	Bovine meat products	ProcessedF / Processed foods
	omt	Meat products nec	
	mil	Dairy products	

	vol	Vegetable oils and fats	
	pcr	Processed rice	
	sgr	Sugar	
	ofd	Food products nec	
	b_t	Beverages and tobacco products	

Energy, fossil fuels and water

The selection made here is made such that the most emitting sectors are separated. The sectors in the top 15 most polluting sectors are highlighted.

Number	**Code**	**Description**	**Aggregation**
7	**oil**	Oil	Oil
8	**coa**	Coal	Coal
9	**gas**	Gas: extraction of natural gas, service activities incidental to oil and gas extraction excluding surveying	Natural Gas
	gdt	Gas manufacture, distribution	
10	**p_c**	Petroleum, coal products	Oil_pcts / Petroleum & coal products
11	**ely**	Electricity	Electricity
12	**wtr**	Water	Water

Low-tech manufacturing

We have aggregated the following subsectors into low-technology manufacturing, similarly to how it is done in WorldScan simulations.

Number	**Code**	**Description**	**Aggregation**
13	**tex**	Textiles	LowTechMan / Low-tech manufacture
	wap	Wearing apparel	
	lea	Leather products	
	lum	Wood products	
	ppp	Paper products, publishing	
	omf	Manufactures nec	

Metals and minerals

We have separated most metals and minerals subsectors due to the fact that they are high-emissions sectors.

Number	**Code**	**Description**	**Aggregation**
14	**nmm**	Mineral products nec manufacture of non-metallic mineral products	MineralProd / Mineral products
15	**i_s**	Ferrous metals: iron and steel: basic production and casting	FerrousMetal / Ferrous metals
16	**nfm**	Metals nec: non-ferrous metals, production and casting of copper, aluminium, zinc, lead, gold and silver	OtherMetals / Other metals
17	**fmp**	Metal products: manufacture of fabricated metal products, except machinery and equipment	MetalProd / Metal products
18	**oxt**	Other Extraction (formerly omn Minerals nec) other mining extraction, mining of metal ores, other mining and quarrying	OtherExtr / Other extraction

Chemical, rubber and plastics

We have separated chemical products due to the fact that it is a high-emissions subsector.

Number	Code	Description	Aggregation
19	**chm**	Chemical products	Chemical
20	**bph**	Basic pharmaceutical products	Pharmaceutical, rubber & plastics
	rpp	Rubber and plastic products	

Machinery, electronic equipment

Number	Code	Description	Aggregation
21	**ome**	Machinery and equipment nec	MachElectron / Machinery & electronics
	mvh	Motor vehicles and parts	
	otn	Transport equipment nec	
	ele	Computer, electronic and optical products	
	eeq	Electrical equipment	

Construction and housing

Number	Code	Description	Aggregation
22	cns	Construction	Construction

Service industry

Number	Code	Description	Aggregation
23	**afs**	Accommodation, Food and service activities	PrivateServ / Private services
	whs	Warehousing and support activities	
	cmn	Communication	
	ofi	Financial services nec	
	ins	Insurance (formerly isr)	
	rsa	Real estate activities	
	obs	Business services nec	
	ros	Recreational and other services	
	dwe	Dwellings	
24	**osg**	Public Administration and defense	PublicServ / Public services
	edu	Education	
	hht	Human health and social work activities	

Transport and trade

Number	Code	Description	Aggregation
25	**trd**	Trade: wholesale and retail trade, repair of motor vehicles and motorcycles	Trade
26	**otp**	Transport nec land transport and transport via pipeline	OtherTransp/ Land and pipeline transport
27	**wtp**	Water transport	WaterTrans/ Water transport
28	**atp**	Air transport	AirTrans / Air transport

8.3 Appendix III: Data and main assumptions

8.3.1 Baseline

Table AIII.1: Data sources used for the construction of the baseline

Baseline data	Data Name	Source
Percentage GDP change 2014-2019	GDP (constant 2010 USD)	World Bank national accounts data, and OECD National Accounts data files.
Percentage labour change 2014-2019	Population ages 15-64, total	World Bank staff estimates using the World Bank's total population and age/sex distributions of the United Nations Population Division's World Population Prospects: 2019 Revision.
Percentage population change 2014-2019	Population total	World Bank – World Development Indicators
Percentage CO_2 emission change 2014-2018	Sum of 'CO_2_excl_short-cycle_org_C' over all economic activities	EDGAR database; The value for 2019 has been obtained by extrapolating the 2018 value using the yearly average growth rate of 2014-2018
Estimated percentage GDP change 2020-2030	Real GDP long-term forecast (2020-2030)	OECD data
Estimated percentage labour change 2020-2030	Population ages 15-64, total (2020 and 2030)	World Bank – Data bank, Population estimates and projections
Estimated percentage population change 2020-2030	Total population (2020 and 2030)	World Bank – Data bank, Population estimates and projections
Estimated percentage CO_2 emission change 2020-2030	Change per capita emissions 2010-2030	UNEP (2019) Gap report 2019, table 2.2, p. 11

For the 2020-2030 estimations of percentage changes for GDP and emissions, some assumptions needed to be made for certain countries and regions due to the fact that the OECD estimates and the UNEP Emission Gap Report 2019 did not provide estimates for all countries and regions.

Table AIII.2: Assumptions per region

Country/world region in GTAP aggregation	GDP 2020-2030	Emissions 2020-2030
RestAsia	Increase in GDP assumed to be the same on yearly basis as in the period 2014-2019	Estimated using this region's estimated share of world emissions in 2030; the share of world emissions in 2030 is estimated using the share of 2018 and assuming that the share will grow with the same average yearly rates as in the period 2010-2018.
RestAM	Increase in GDP assumed to be the same on yearly basis as overall world GDP increase in 2014-2019	Same as above.
Romania	Increase in GDP assumed to be the same on yearly basis as in 2014-2019	The same change of per capita emissions between 2010 and 2030 has been assumed than for the EU.
RestEU	Increase in GDP assumed to be the same on yearly basis as in 2014-2019	Estimated using this region's estimated share of world emissions in 2030; the share of world emissions in 2030 is estimated using the share of 2018 and assuming that the share will grow with the same average yearly rates as in the period 2010-2018.
Iran	Increase in GDP assumed to be the same on yearly basis as in 2014-2019	Same as above.
RestofEurope	Increase in GDP assumed to be the same on yearly basis as in 2014-2019	Same as above.
RoW	Increase in GDP assumed to be equal to estimated world GDP growth for period 2020-2030	Same as above.

With regard to 2030 emissions estimates based on the UNEP Emission Gap Report, several further assumptions needed to be made:

- The changes in per capital emissions between 2010 and 2030 in Table 2.2 of the UNEP Emission Gap Report (2019) were given for all greenhouse gases, i.e. including methane and nitrous oxide. We have assumed that that the percentage changes enlisted in the table would hold for CO_2 only. This probably underestimates the possible emissions reductions in CO_2 since reducing CO_2, especially as a consequence of burning fossil fuels, is seen to be easier than methane or nitrous oxide, which are emissions predominantly related to agriculture and therefore harder to abate.

- The UNEP Emission Gap Report (2019) estimates that the total CO_2-equivalent emissions in 2030 will be around 60 $GtCO_2e$, according to the ‘current policies’ scenario. For computing the 2030 CO_2 emissions, we assumed that the current shares of CO_2 emissions to other non-CO_2 greenhouse gas emissions stays constant. This, however, is a simplifying assumption, as explained above.
- The UNEP Emission Gap Report (2019) reports only one number for E28. Therefore, we assumed that the same percentage emissions reduction applies the EU28 countries we singled out in the model analysis. This is a simplification – while having a common emission reduction goal, the EU allows countries to reduce their emissions in different speeds, depending on their decarbonisation possibilities and economic development.
- The EU’s percentage emission reductions are assumed to hold also for the UK and the EFTA countries.

8.3.2 Scenarios

Two tax rates are employed per scenario.

Three scenarios are constructed, each analysing the effects of the tax in different geographical jurisdictions.

Scenario 1 – Carbon tax in the Netherlands only

Scenario 2 – Carbon tax in the EU+ which includes UK and EFTA countries (see detailed list below).

AUT	**Austria**	Austria
BEL	**Belgium**	Belgium
CZE	**Czech Republic**	Czech Republic
DNK	**Denmark**	Denmark
FIN	**Finland**	Finland
FRA	**France**	France
DEU	**Germany**	Germany
GRC	**Greece**	Greece
HUN	**Hungary**	Hungary
IRL	**Ireland**	Ireland
ITA	**Italy**	Italy
NLD	**Netherlands**	Netherlands
POL	**Poland**	Poland
PRT	**Portugal**	Portugal
ROU	**Romania**	Romania
ESP	**Spain**	Spain
SWE	**Sweden**	Sweden
BGR	**RestEU**	Bulgaria
HRV		Croatia
CYP		Cyprus
EST		Estonia
LVA		Latvia
LTU		Lithuania
LUX		Luxemburg
MLT		Malta
SVK		Slovakia
SVN		Slovenia
NOR	**EFTA**	Norway
CHE		Switzerland
XEF		Rest of EFTA (Lichtenstein and Iceland)
GBR	**UK**	United Kingdom

Scenario 3 – Carbon tax in the EU+ (EU, UK and EFTA) and in the following countries:

Number	Code	Aggregation	Description
1	AUS	**Australia**	Australia
2	NZL XOC	**Rest Oceania**	New Zealand Rest of Oceania
3	CHN HKG	**CHG**	China Hong Kong, Special Administrative Region of China
4	JPN	**Japan**	Japan
5	KOR	**Korea**	Korea, Republic of
7	CAN	**Canada**	Canada
8	USA	**USA**	United States of America