DREAM
Danish Research Institute for
Economic Analysis and Modelling

GREEN REFORM

Macroeconomic Effects of a 350DKK uniform carbon Tax

Preliminary results March 2022 - please do not cite

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1. Introduction

This section introduces the main purpose of this memo and outlines the main pitfalls of the foundation of the analysis at hand.

This memo describes the effects of an implementation of a Danish greenhouse gas emission tax (henceforth referred to as carbon tax) in the current preliminary version of the dynamic CGE-model GreenREFORM.

The analysis presented illustrates the qualitative effects of a carbon tax, in terms of macroeconomic and sectoral effects in GreenREFORM. Even though the exact figures will diverge from the final model, the general dynamic effects, as outlined in this memo, are likely to remain.

The results presented in this note is of a preliminary nature. They should not be interpreted as painting the full picture of effects of similar policies in practice. The note is published based on a wish for openness in the development of the model and to encourage professional discussion about GreenREFORM. Please do not cite without prior agreement.

The main outstanding issues of the current model version include[1]:

- **No explicit modelling of transport:** The GreenREFORM module on transportation is not yet operational. As above, this means that transport services are modelled as standard production sectors that produce using capital, labour and other inputs, resulting in a rigid fuel mix.
- **The cement industry:** The cement industry is included in a larger and much less CO2-intensive sector at present, implying that a change in the costs of production of cement does not lead to a similarly significant loss of competitiveness.
- **We employ provisional technology data for industry only, ie. no information on technologies for agriculture etc.:** The data set is provided by the Danish Energy Agency, and cover technologies for industrial processes, which becomes profitable at up to 300 DKK per tCO2e compared with baseline.

More information about the model, including several documentation memos and research papers, is available at greenreform.dk.

The outline of the rest of this memo is as follows. Section 2 describe the implemented carbon tax in detail. Section 3 examines the macroeconomic effects of the tax. Section 4 displays and discusses the sectoral effects of a carbon tax with a focus on the changes in emissions.

[1] Other issues and concerns are raised in the analysis.

2. Shock description

This section will describe the carbon tax shock. The section covers the tax rate, implementation process and the handling of existing carbon taxes.

The forthcoming results is based upon a uniform carbon tax shock which is introduced in 2020 and linearly phased in from 2023 to 2030 reaching the level of 350 DKK per ton CO_2e, measured in 2021 prices.

The tax level of 350DKK is chosen to ensure, that all abatement opportunities described in our data are utilised (with a margin), as all technologies, which becomes profitable at up to 300 DKK per tCO2e.

The tax is levied on carbon dioxide, methane and nitrous oxide. All energy related and non-energy related CO_2e-emissions covered by the UNFCCC-definition of danish territorial emissions are covered by the tax, including emissions inside the ETS-system.

As the uniform CO2e-tax is phased in, the existing carbon taxes (CO_2-afgift) are phased out in parallel towards 2030. As the current carbon tax vary between 0-170 DKK per ton CO_2e for industrial use of energy, the shock represents a significant consolidation of the Danish climate policy. For households, the uniform 350 DKK CO2e-tax is on par with existing taxes.

Other taxes levied on the use of energy are left in place (energi-afgift mv.). Note however, that in the current version of the model, the ETS-price is not explicitly internalized in the input-decision of firms, even if the model do account for energy use covered by ETS in each sector. This can be interpreted as the CO2e-tax being levied on top of the ETS-price, hence firms covered by the ETS will be facing a higher CO2e-price than firms outside the ETS.

The tax itself and all windfall gains, be they positive or negative, are fully financed year by year, as the Government primary budget balance is kept in check with the baseline by a yearly lumpsum transfer to the households. Household behaviour is at present modelled simplistically with a backward looking response in private consumption to changes in income and wealth. This is inspired by the macro-econometric model ADAM.

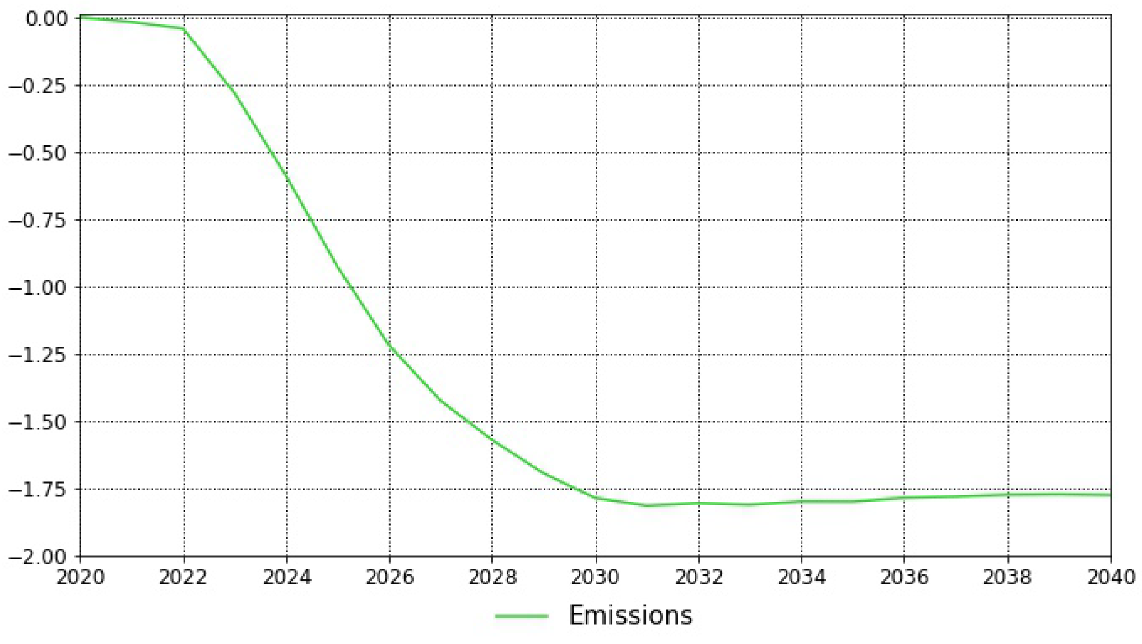
3. Macroeconomic effects

The present section will contemplate the macroeconomic effects of the previously specified carbon tax including the dynamic effects on the GDP-deflator, GDP, wages, unemployment, investments, exports and emissions.

This section will consider the macroeconomic effects of a carbon tax of 350 DKK per ton CO_2e measured in 2021 prices as described in the previous section. The carbon tax is announced in 2020 and linearly phased in from 2023 until 2030. The long-term effect is a decrease in emissions of DKK 1.75 million. CO2e and a fall in GDP of 0.08 per cent.

As reflected in figure 3.5, emissions will decrease with 1.8 million tons of CO_2e in 2030 compared to baseline levels. The emission level after the shock is estimated to be 30 million tons of CO_2e in 2030. In order to achieve the 2030 target, the emission must reach a level of 23.23 million tons of CO_2e cf. Danish Energy Agency (2021). Thus, the effects of the carbon tax covers only a fraction of the total required abatement in relation to the 2030 target.

Figure 3.1
Emission changes from baseline measured in million tons of CO_2e



Source: Own calculations based on GreenREFORM:

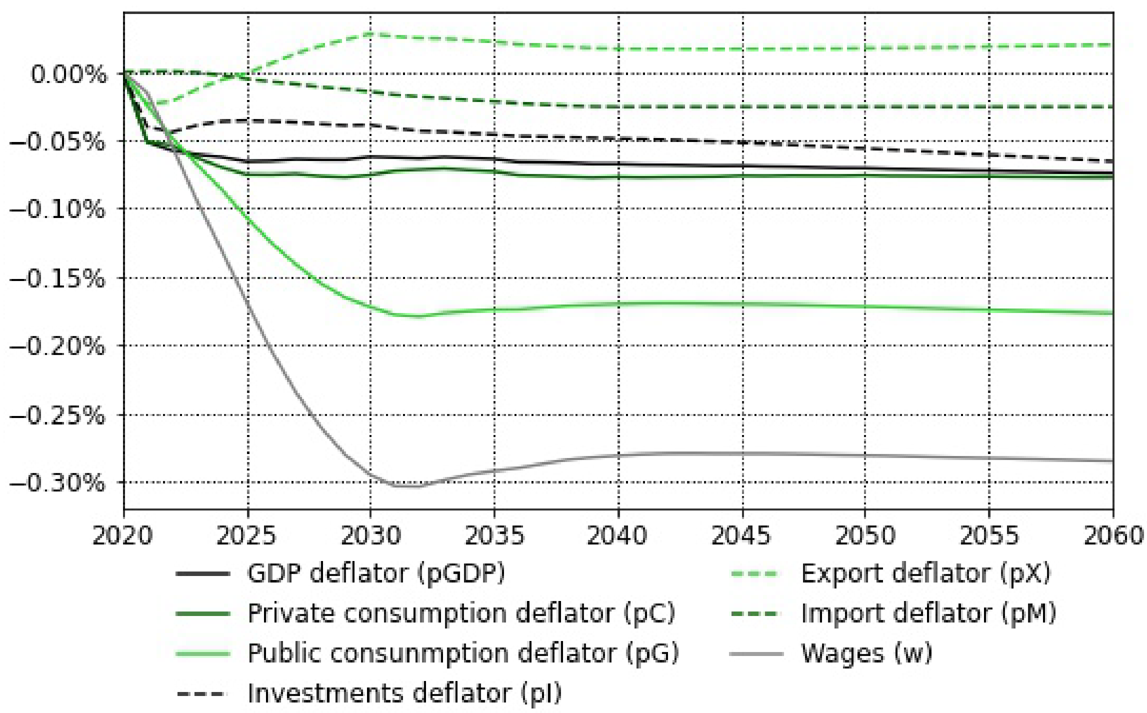
Looking at the direct impact of the CO2-tax, CO2e-intensive businesses with a priori low level of CO2-tax (CO2-afgift) like cement, agriculture fishing etc. are obviously most affected, while households are largely unaffected.

The immediate effect of a higher carbon tax is higher production costs, and thus a loss of competitiveness. This affects the economy differently in the short and long term. In Long term, the deterioration of firms' profitability and competitiveness will drive wages down, and firms will thus substitute from capital to labour, so that GDP falls for a given structural employment. This is the driving force behind the long-term GDP loss, cf. figure 3.2.

Figure 3.2 shows the effect on GDP and its components. GDP falls 0.8 percent in long term. An initial large effect is seen on investments. This is a classic result, due to the fact, that it requires significant (dis-) investments to adjust the large capital stock towards the new long term equilibrium. The long term decline in the total capital stock also results in investments being permanently lower compared to baseline.

Before we look at the other components of GDP, it worth while having a look at the impact on prices in the economy, cf. figure 3.2. Prices are affected by two factors: the higher carbon tax and the lower wages. Wages fall by about 0.3 percent in the long term, and the net effect on prices is almost neutral. The CO2 tax affects manufacturing more than service. As exports largely come from manufacturing, it can be seen, that the export price is growing as a result of the higher CO2 tax. The rest of the prices fall. Due to the high wage content in the public sector, unit costs in the public sector are falling relatively much.

Figure 3.2
GDP-components' deflator changes from baseline in percentage

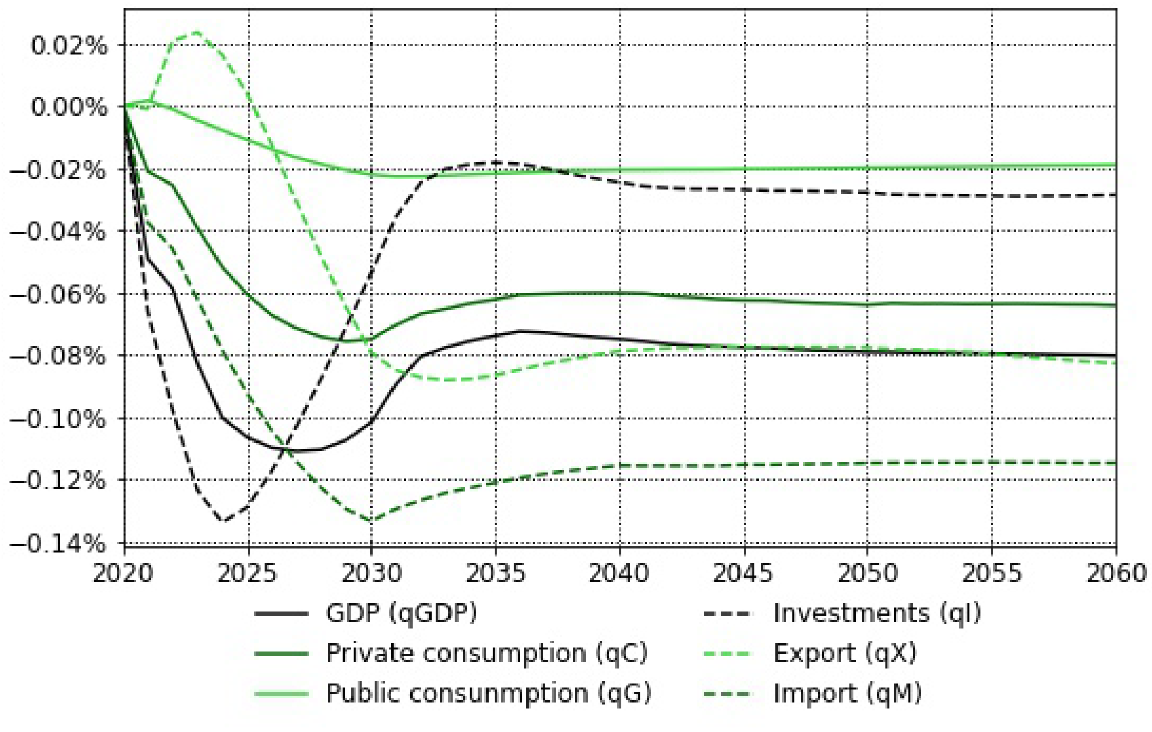


Source: Own calculations based on GreenREFORM:

Figure 3.2 also shows that in the short term prior to the implementation of the tax increase, prices are falling. This is due to declining demand, generated by declining investments of forward-looking firms. This is reflected in the prices, due to the model's two central short-term rigidities. First, the wage is modeled via a classic backward-looking Phillips curve. This causes the wage to react sluggishly. Secondly, there is a real rigidity in exports. Exports are reacting slowly to changes in the export price. These two effects are central to achieving Keynesian short-term effects in a small open economy. Figure 3.4 thus shows a classic Keynesian effect on unemployment.

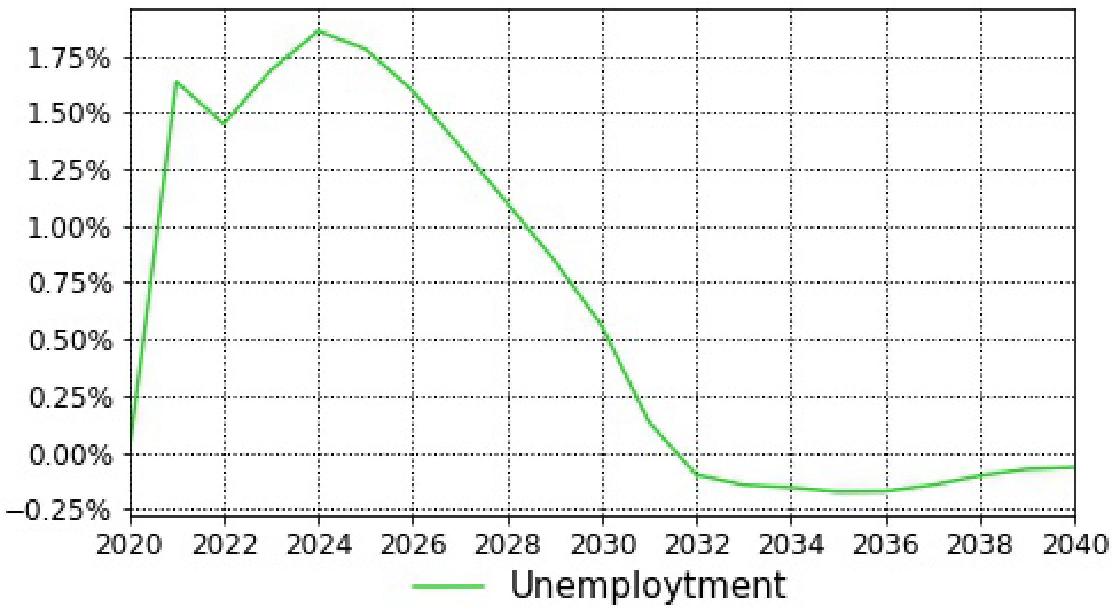
Let us now turn to the quantities. Figure 3.3 shows that exports are falling in the long term due to higher export prices. Imports are falling even more due to falling domestic prices. In the short term, there is a small increase in exports due to falling export prices. As mentioned earlier, investment is declining slightly in the long term because the capital stock is declining. There is an only moderate decline in private consumption, which is. due to the fact, that the revenues from the CO2 tax are repaid to the households in the shock considered here.

Figure 3.3
GDP-components changes from baseline compared to BNP in baseline percentage



Source: Own calculations based on GreenREFORM:

Figure 3.4
Unemployment changes from baseline in percentage



Source: Own calculations based on GreenREFORM:

4. Sectoral effects of the carbon tax

This section will consider the effects of a carbon tax on the firms. This includes a decomposition of the dynamic effects on the production of the sectors and the subsequent sectoral price setting and a broad investigation of the sector-specific emission changes.

The effects of the carbon tax on the firms can be categorized into three distinctive channels:

1. The first-order effect of the carbon tax is increased production costs, that are larger in CO2e-intensive sectors. Increased production costs give rise to increased prices as the marginal costs dictate the output prices. Moreover, the increased prices of the goods leads to a drop in the demand. Everything else equal, a carbon tax will lead to decreased demand of the carbon intensive goods, and thus lower **output**. Additionally, sectors that have a large share of exports are more exposed to such changes in demand, as the export demand own price elasticities are higher than the effective price elasticities in domestic demand.
2. The implemented production functions allow firms to **substitute** away from the polluting inputs and towards other non- or less polluting inputs such as labor, capital and other materials. This effect causes the firms' CO2e-intensity and their emissions to decline.
3. Firms react to the increasing carbon tax by investing in **abatement technologies.** However, the availability of these technologies vary across the sectors. For instance, manufacture of food products use substantial amounts energy on low-temperature processes such as drying. These processes can be electrified, which in turn reduces fossil fuel consumption and therefore emissions. On the other hand, the cement industry is reliant upon very high temperatures that cannot easily be electrified.

The last two effects reduce the CO_2e-intensity. Reductions in the intensity counteracts the first order effect of the carbon tax, as the reductions in intensity decreases the output price. This reflects the so-called rebound effect, which is well understood in the literature on environmental economics, but sometimes ignored in partial analyses of e.g. technological potentials of emissions reductions.

Based on the three effects above the abatements in each sector can be decomposed into one part caused by changes in output, one part caused by substitution and one part caused by abatement technologies. Figure 4.1 and 4.2 reflect this decomposition as they illustrates the percentage and absolute change in emissions from the baseline scenario in 2030 across sectors, respectively. Both figures are sorted according to their percentage decrease in emissions.

As evident in both figures, the emission changes are driven by a varying degree of changes in output, abatement technologies and substitution across the sectors. In the industrial sectors, where abatement technologies are available , this is the most important effect. However, some sectors, such as the agricultural sectors, have fewer substitution possibilities.

Some carbon extensive sectors increase their output. This is due to their ability to capitalize on the general equilibrium effect that causes the decline in wages[2], cf. section 3, as the effect diminishes the production costs in labor-intensive sector. Pharmaceuticals is the most striking example, as they produce mostly for export demand, which is more price sensitive than domestic demand.

Comparison of figure 4.1 and 4.2 reveals that the relative emissions changes do not embody the magnitude of the absolute emissions changes. The most significant absolute emission changes arise in sectors independently of their relative emission changes, namely air transport, non-metallic minerals and agriculture. Combined, these sectors abate more than 1 million tons of CO_2e, which is more than 60 percent of the total abatements in 2030, cf. figure 3.5.

As described in section 1, the presented results on the basis of a simulation of the current version of GreenREFORM must be considered with vigilance as several aspects of the model is yet to be developed and integrated:

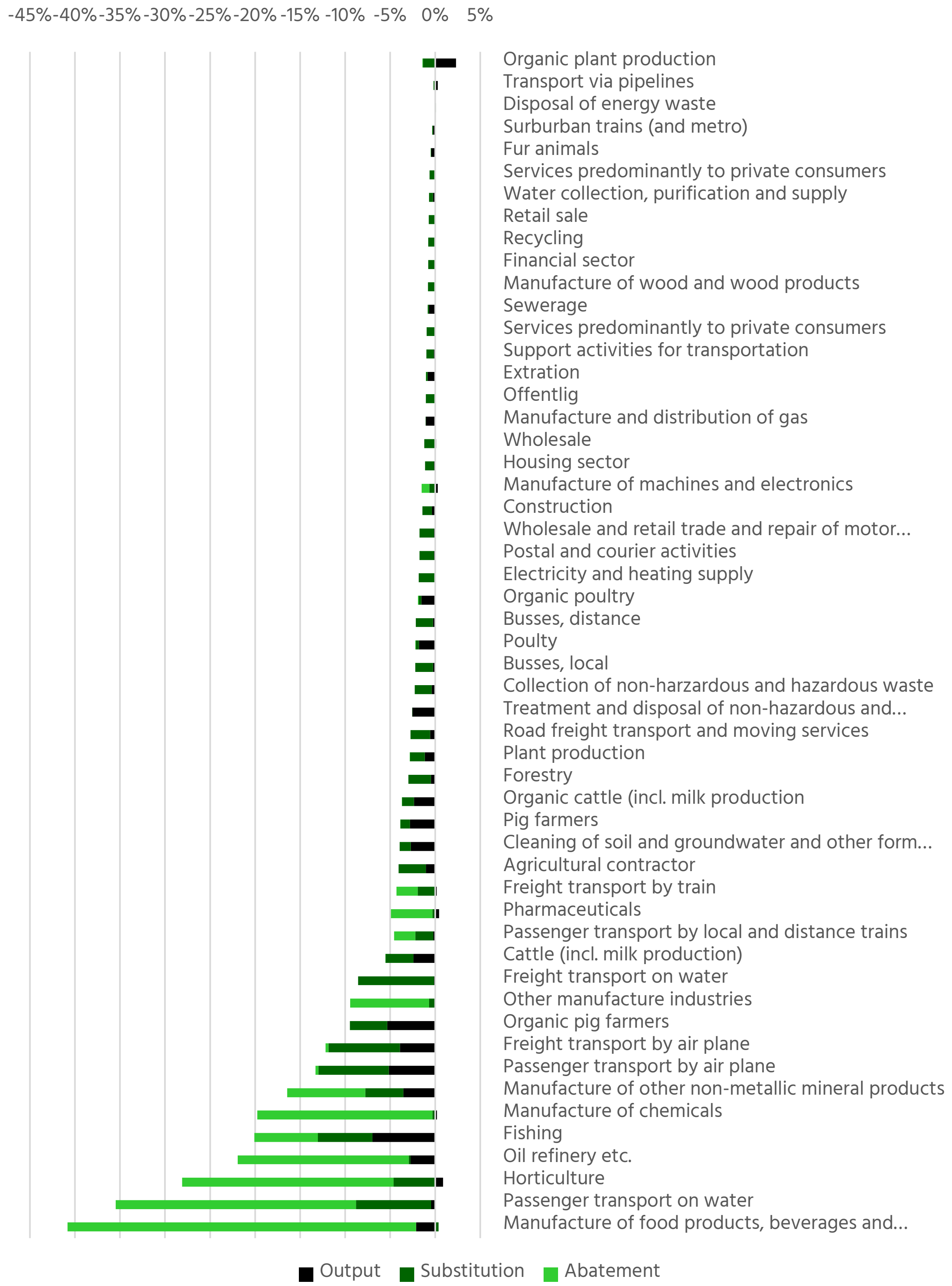
The change in output prices of sectors in GreenREFORM are in general proportional to the change in average production costs of the firms. Oil and gas extraction in the Northsea and agriculture are notable exceptions. The price of oil and gas is fixed to baseline values, and oil and gas production is also fixed, subject to variation in the rate of profit. In effect, agriculture is very similar, due to land being a fixed primary factor: Land can move between agricultural sectors, but there is a fixed total amount of land available for agricultural use, which must be employed, subject to changes in the land rent. Hence, land rents adjusts for most of any change in the costs of production of plant production (to be specific), and henceforth, output prices and production levels are extremely rigid.

It is possible that the scale of production in some cases is too rigid in the model. Extraction of oil and gas and agriculture are prime candidates. Cement-production, which is in effect hidden in a larger sector, is yet another. In other cases, the demand response may be too elastic. In extreme, this would be the case if firms are operating at given world market prices, and will choose to keep production going at any level of profits. This is the implicit assumption in how Agriculture and Extraction of oil and gas is modelled at present. More generally, it would also be the case, if the demand elasticities we employ are too high.

GreenREFORM relies on explicit exogenous information on abatement technologies. As explained in section 1, in the present analysis, we employ a provisional technology catalogue for industry only, hence there is no abatement opportunities in agriculture, transport, or household use of energy. Of the total 1,8 mio CO2e in emissions reductions (cf. figure 3.5), 0,65 are directly related to adoption of abatement technologies in the industrial sectors.

[2] And declining land rents in the case of organic plant production at the top of figure 4.1, due to the functioning of the land market, as explained below.

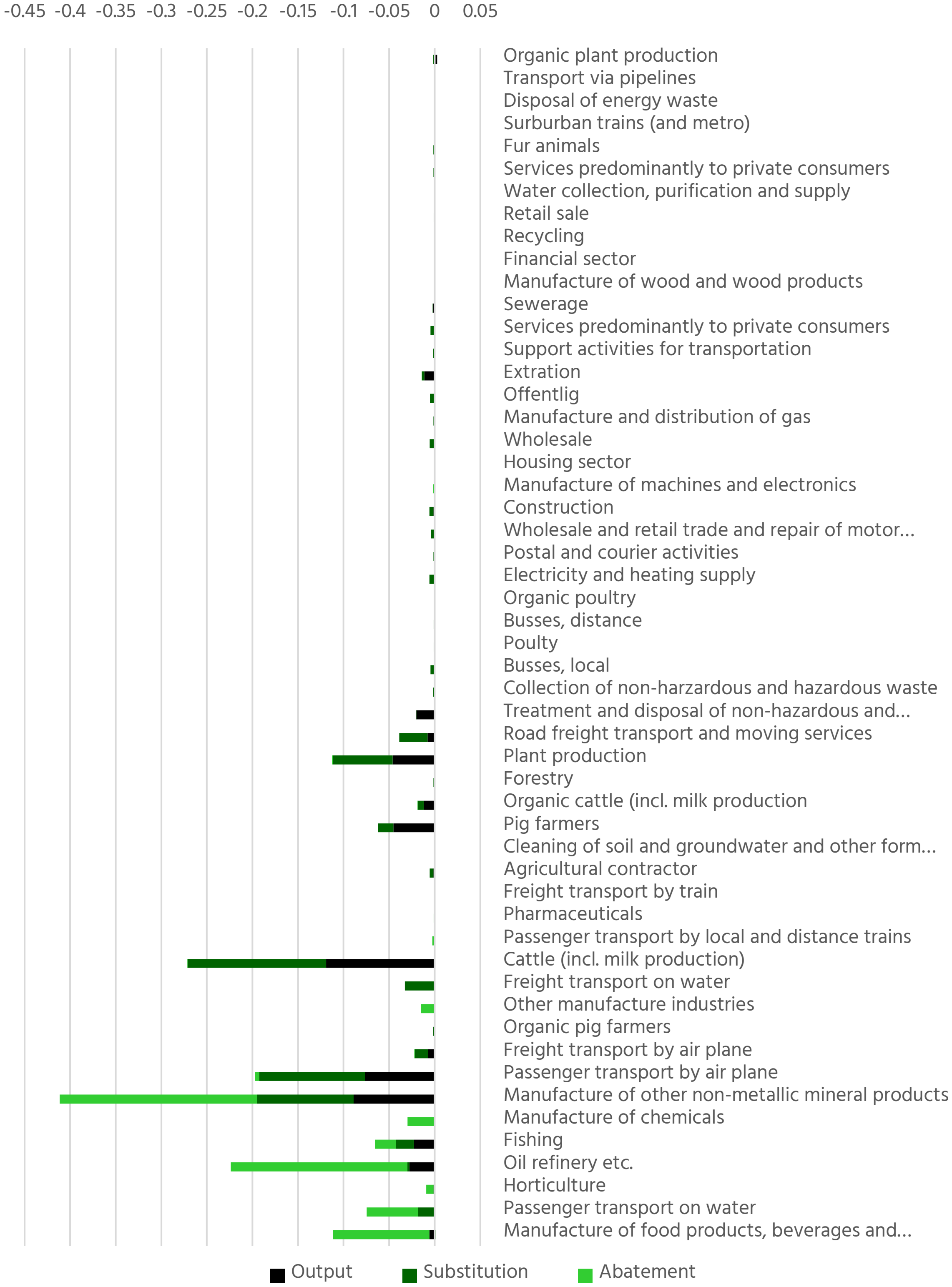
Figure 4.1
Decomposed sectoral emissions changes from baseline in percentage in 2030



Source: Own calculations based on GreenREFORM

Figure 4.2

Decomposed sectoral emissions changes from baseline measured in million tons CO_2e in 2030



Source: Own calculations based on GreenREFORM

5. References

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