Occasional Studies
Volume 16 - 8

The price of transition

an analysis of the economic implications of carbon taxing

DeNederlandscheBank
EUROSYSTEEM

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The Occasional Studies aim to disseminate thinking on policy and analytical issues in areas relevant to De Nederlandsche Bank. Views expressed are those of the individual authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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We are grateful to Jan Marc Berk, Barbara Kölbl and Steven Poelhekke for their valuable comments to previous versions of this study.

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Preface

In the summer of 2018, the House of Representatives of the Netherlands supported the legislative proposal for a Climate Act. The Climate Act stipulates that in 2050, greenhouse gas emissions must have been reduced by 95% relative to their 1990 level. To achieve this objective, the government is aiming to reduce emissions by 49% in 2030. This requires ambitious climate policies, which also include the option of introducing a direct tax on carbon emissions. An efficient way of reducing harmful emissions is to assign a price to the external effects of emissions. Data evidences that compared with other countries, Dutch enterprises emit large quantities of greenhouse gases and are paying relatively little for these emissions. The most straightforward approach would be to introduce a European carbon tax, after the example of the European Emissions Trading System (ETS). The option of introducing a national policy, with the Netherlands leading the field in terms of imposing a direct carbon tax on corporations, requires more insight into its impact on production costs, international price competitiveness and sales. This study addresses this, distinguishing between the various industry sectors within the Dutch economy.

1 Corporate sector greenhouse gas emissions

Carbon emissions caused by the Dutch corporate sector are higher than those in other European countries and are decreasing at a substantially lower pace. This chapter explains that this fact is closely related to the specific characteristics of the different industry sectors. The manufacturing industry, including chemicals and base metals, is causing particularly high levels of carbon emissions. Its energy consumption is higher in the Netherlands than elsewhere in Europe, it uses more fossil fuels, and it manufactures more carbon-intensive products using more carbon-intensive production processes.

1.1 High carbon emissions due to fossil energy

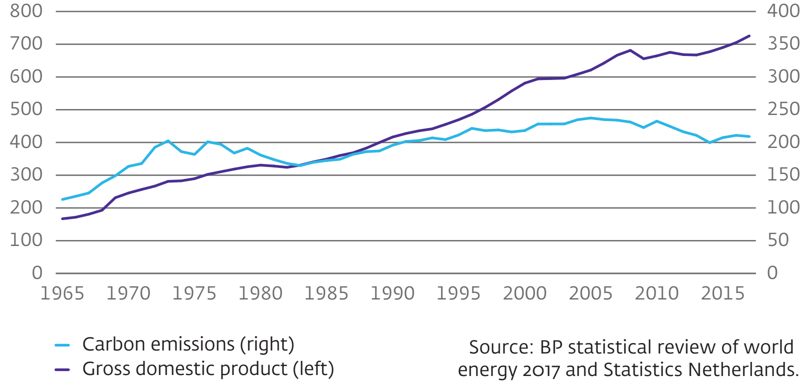
The broadly supported legislative proposal for a Climate Act stipulates that in 2050, greenhouse gas emissions must have been reduced by 95% relative to their 1990 level. To achieve this objective, the government is aiming to reduce emissions by 49% in 2030. Judging by the developments seen in the past decades, this is an ambitious objective. That said, the long-term upward trend in carbon emissions seems to be slowing down, and has recently even been showing signs of reversal.[1] The current level of carbon emissions in the Netherlands is below its previous peak of 2006, and is nearing the 1990 level. Since 2006, carbon emissions have *declined* by 12% (in 2015), while gross domestic product (GDP) has *grown* by 11% (see Figure 1).[2]

Although this development is encouraging in itself, it does not mean that the Dutch corporate sector is leading the field in reducing carbon emissions. Emission intensity, i.e. the volume of emissions per unit of value added (at constant prices) is substantially higher in the Netherlands than in the

1 This study defines carbon emissions as the emission of all greenhouse gases expressed in CO_2 equivalent units. This means that emission intensity also includes emissions of methane gas for instance, and emissions resulting from processing of fossil fuels into plastics and other products.
2 Adjusted for price rises. GDP is the measure for all goods and services produced by a country's corporate and public sector in one year.

Figure 1 Carbon emissions and GDP in the Netherlands

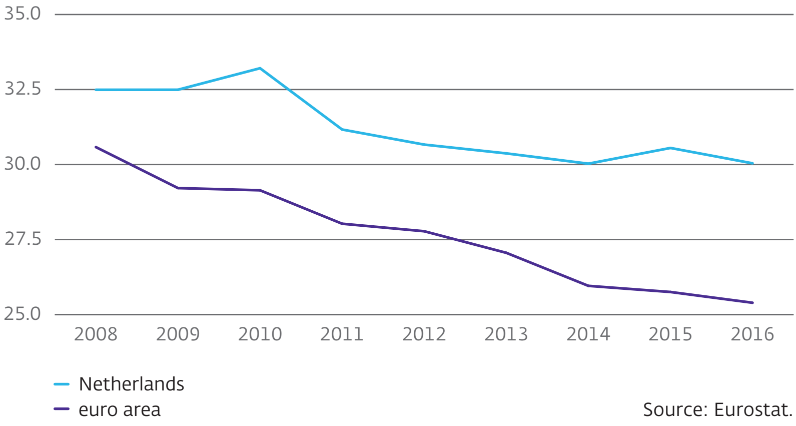
Millions of tonnes and EUR billion (2010 prices)



Source: BP statistical review of world energy 2017 and Statistics Netherlands.

Figure 2 Emission intensity of the corporate sector in the Netherlands and the euro area

In kilogrammes of CO_2 equivalent per EUR 100 gross value added (2010 prices)



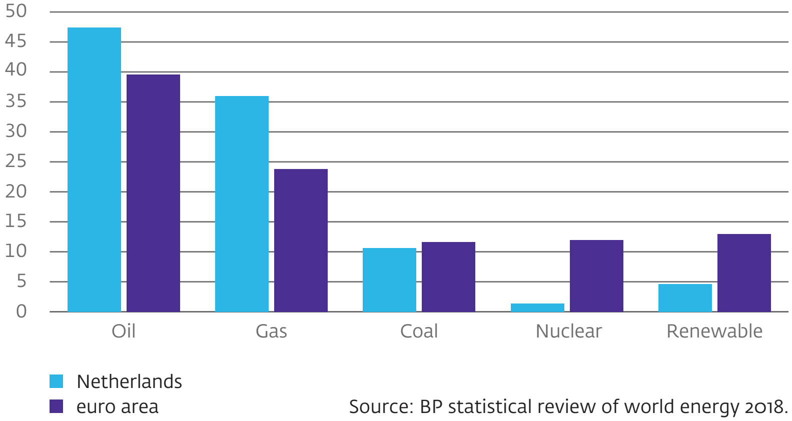
Source: Eurostat.

euro area. This gap even widened slightly in the past few years, and in 2016 came to around one third of the European level (see Figure 2). The Dutch corporate sector's heavy carbon footprint relative to the euro area is due in particular to the country's significantly higher average carbon-intensive energy consumption. Energy consumption itself in the Netherlands has meanwhile declined to the European average.[3]

The higher carbon content of energy consumption is reflected in the distribution of consumed energy across the various energy sources.[4]

Figure 3 Energy mix in the Netherlands and the euro area

Percentages of total energy consumption; 2017



Source: BP statistical review of world energy 2018.

3 Measured by energy intensity, i.e. total energy consumption relative to value added, at constant prices. The decline of energy intensity only halted following the 2001 recession and the euro crisis in 2010, partly due to less optimal energy consumption as a consequence of capacity underutilisation and lower investment in energy-efficient production processes (ECN, 2015).

4 This is the mix of primary energy sources, so excluding electricity, but including coal, gas, and renewable sources for electricity generation. In this chapter, energy consumption is depicted excluding fossil energy carriers used as direct input in the production process (mainly oil, but also gas), e.g. crude oil feedstocks for the production of plastics, or the use of natural gas for the production of fertiliser. In 2016, around 40% of the total consumption of energy carriers in the manufacturing industry consisted of this "non-energetic consumption." This causes significantly less emissions (or sometimes even none at all) on average during the production process.

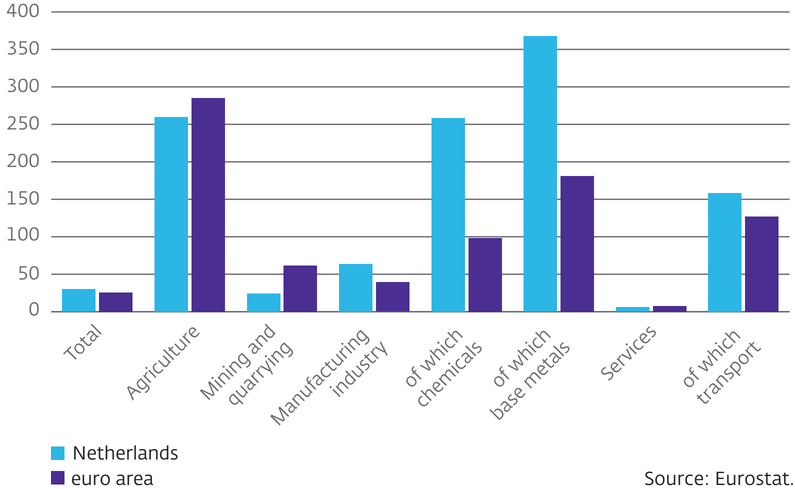
In the total energy mix, the Netherlands accounts for a relatively high share of fossil energy sources (oil and gas) and a low share of renewable energy and nuclear power (see Figure 3).

1.2 Specific Dutch industry sectors specialise in emission-intensive products

The higher carbon footprint of the Dutch corporate sector as a whole compared to other euro area countries is particularly discernible in a small number of specific industry sectors. The heaviest adjustment burden to achieve nation-wide emission reduction therefore rests with these sectors. Figure 4 shows that emission intensity is particularly high in the chemicals

Figure 4 Emission intensity by industry sector in the Netherlands and the euro area

In kilogrammes of CO_2 equivalent per EUR 100 gross value added (2010 prices); 2016



Source: Eurostat.

and metals industries. In these two sectors, emissions per unit of value added in the Netherlands are more than twice the euro area average. The transport sector also accounts for relatively high emission intensity.

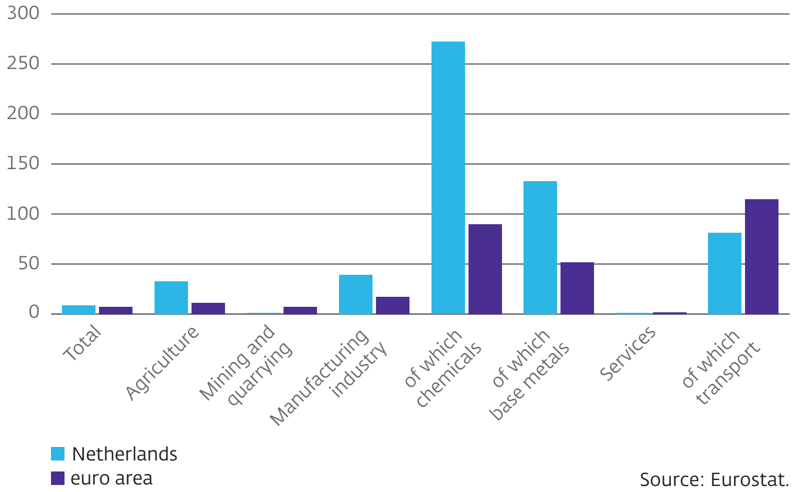
The higher emission levels recorded in specific industry sectors are mainly due to specialisations in carbon-intensive activities *within* those industry sectors. The chosen industry sector classification is therefore too coarse for a detailed explanation. Although there is no hard evidence to support this, there are strong indications that the higher carbon emission levels seen in the chemicals, metals and (to a lesser extent) transport sectors in the Netherlands are attributable to a different product mix than that produced abroad. These industry sectors specialise in products that cause relatively high carbon emissions.

In the manufacturing industry, the largest emissions by far are produced by three industry sectors and sub-sectors: oil refining, chemicals and steel. These sectors specialise in very high emission-intensive products like primary steel production from iron ore, as well as diesel and shipping industry fuels, which cause relatively high carbon emissions and are energy-intensive (ECN, 2018a; CE Delft, 2014). The bulk of the carbon footprint of the Dutch chemicals sector is attributable to the petrochemicals industry, more in particular to manufacturing of a number of specific energy and carbon emission-intensive products. Two very emission-intensive processes (naphtha cracking and steam reforming) alone are responsible for more than three quarters of total emissions produced by the chemicals industry (ECN, 2018b), and almost half of this industry's energy consumption (CE Delft, 2014).[5] Partly due to this, the Dutch chemicals sector has a very high energy intensity compared with the euro area (see Figure 5).

5 These processes are responsible for an estimated 40% of energy consumption in the chemicals industry, excluding the consumption of energy as a feedstock in the production process.

Figure 5 Energy intensity by industry sector in the Netherlands and the euro area

In kilogrammes of oil equivalent per EUR 100 in gross added value (2010 prices); 2016



Source: Eurostat.

The higher emission intensity in the Dutch transport sector is primarily attributable to the larger share of shipping. The transport sector often uses fuels with higher carbon content (heating oil). The high emissions levels are also due to a relatively large contribution from the emission-intensive aviation industry. The Dutch aviation industry is responsible for 47% of transport sector emissions, relative to 35% for the euro area.

Emissions in the Dutch agricultural industry on the other hand are somewhat lower than those in the euro area, although more energy is used in the Netherlands. This is related to the relatively clean energy mix in the Netherlands: compared with other EU countries, the Dutch agricultural sector uses relatively large quantities of natural gas and hardly any coal and petroleum products (Eurostat, 2018). The vast majority of the carbon footprint of this sector is accounted for by greenhouse horticulture.[6]

1.3 Implications for climate policies

There are twelve years left to achieve the envisaged 49% reduction of carbon emissions in the Netherlands. This means that additional policies, or tightening of the existing policies is necessary. As explained in the preceding sections, the carbon footprint of the Dutch corporate sector relates to both energy consumption and the energy mix. Both factors deserve attention in climate policies, albeit that Dutch corporations do not deviate much from the European average where energy consumption is concerned. Emission intensity on the other hand is much heavier than in other countries.

Changes in the emissions of individual industry sectors may feed through to the national average of emission intensity. The national intensity, however, also changes if specific industry sectors expand and others shrink, amid unchanged emissions within these sectors. However, in the Netherlands, the reduction of emission intensity is largely attributable to developments within individual industry sectors.

6 That said, carbon emissions only account for one third of the total of greenhouse emissions in the agricultural sector: the majority is attributable to dairy farming in the form of methane. See also CE Delft (2014), Emissions registration (2018), Mulder and De Groot (2013).

This can be estimated in a “shift-share analysis”.[7] For the Netherlands, this shows that by far the largest part of the reduction of emission intensity is related to reduced emissions within the individual industry sectors. 33.5 percentage points of the 37.5% reduction of emission intensity achieved between 1995 and 2016 is accounted for by developments in individual industry sectors.[8] The remaining 4 percentage points are attributable to the gradual shift in production towards less emission-intensive industry sectors.

The recent decline of energy intensity shows the same pattern. 20 percentage points of the 24% decline between 1995 and 2016 is attributable to energy conservation within industry sectors, with the largest contribution coming from the chemicals industry. The remaining 4 percentage points of the decline is attributable to sectoral shifts, with less energy-intensive sectors expanding relative to more energy-intensive sectors. The shrinking oil sector and mining and quarrying sector have contributed towards this trend. The effect is dampened somewhat by the sharply growing aviation, shipping and chemicals sectors.

7 To learn more about the methodology used, see e.g. Bhattacharyya (2011), p. 85.
8 This shift-share analysis calculates for the 57 individual Dutch industry sectors which part of the total emission or energy intensity between 1995 and 2016 is accounted for by the shift in the relative size of the individual industry sectors, and which part is accounted for by the changes in emission or energy intensity within the individual industry sectors.

2 Energy costs and carbon taxes

This chapter compares energy prices and energy taxes in the Netherlands with those in other European countries. We will also look at how carbon emissions in the Netherlands are taxed. Electricity prices paid by the Dutch corporate sector prove to be relatively low, which also applies to natural gas for bulk buyers. Small corporations in the Netherlands pay higher energy prices than their larger counterparts, mainly due to energy taxation. Although energy taxes may be perceived as indirect carbon taxes, direct taxation of carbon emissions is to be preferred in the interest of an efficient energy transition. The Netherlands, unlike many other developed countries, has as yet no direct carbon taxation in place apart from the European Emissions Trading System (ETS).[9] By international standards, Dutch corporations are paying relatively low prices for their carbon emissions (directly via the ETS, and indirectly through taxation). Furthermore, estimates show that the carbon prices paid by the manufacturing industry are still well below the social costs of carbon emission, so from this perspective there are few objections to the introduction of an additional, direct carbon tax for the Dutch corporate sector.

2.1 Electricity and fossil fuel prices

Electricity is cheap for Dutch corporations as compared with other European countries. Electricity prices in the Dutch industrial sector are lower than those in Germany and France and are also below the European average. European electricity prices for the industrial sector are more or less on a par with those in Brazil, China and Turkey (EC, 2016). Electricity prices in Japan are relatively high while they are relatively low in the United States (OECD 2018a). Within the Dutch corporate sector, electricity prices

9 The European emissions trading system was established in 2005 to facilitate trading of greenhouse gas emission rights. This study uses the abbreviation ETS, rather than the official EU ETS. The ETS covers some 45% of all emissions in the EU, caused by more than 11,000 bulk users of energy (industrial corporations and power plants) and the aviation sector in the European Economic Area.

for small consumers are considerably higher than those for bulk users. Smaller enterprises on the whole come into higher tax brackets, get fewer exemptions, and often pay higher network costs. Nevertheless, electricity prices for smaller energy consumers are also low compared with other European countries (IEA, 2014; Ecofys, 2015).

Natural gas prices in the Netherlands for bulk consumers are slightly below the European average, whereas prices for small consumers are way above the European average (OECD, 2018a). Gas prices in the United States for industrial bulk consumers are, however, substantially lower, owing to the large supply of natural gas from the country's own stock (mainly shale gas) (EIA, 2017). Smaller buyers often have to pay higher gas prices, due to higher taxes. Smaller buyers in the Netherlands pay almost the highest energy tax rate on natural gas of the entire EU. The difference in natural gas taxation between small and large buyers in the Netherlands is in fact the most pronounced of all EU countries.

The prices paid in the Netherlands for derivative oil products like diesel fuel and petrol are average relative to other European countries, but higher than those in the United States (IEA, 2014). In most countries, oil products are taxed through excise duties. For the transport sector, these duties may account for more than half of the energy price paid. As in many other countries, crude oil used as a feedstock is free of tax in the Netherlands (PBL, 2017).

2.2 Carbon taxing as an instrument of climate policy

Without government intervention, the social costs of greenhouse gas emissions are not sufficiently passed on into product prices. This makes the consumption of fossil fuels higher than is socially desirable. This market failure may in principle be remedied by levying a tax that equals the marginal carbon emission damage. In this way, consumers of feedstocks internalise the marginal social costs of emission damage (Pigou, 1920).

In order to price the external effects of greenhouse gas emissions, taxes could be levied on the emissions themselves, or on the energy products that cause emission of greenhouse gases, such as natural gas and coal. The advantage of taxing emissions is that the tax directly targets the originator of the social costs. This will push up the costs of high-emission products relative to lower-emission products. In addition, greenhouse gases not directly related to energy consumption, e.g. emissions during chemical production processes or agricultural methane emissions, could be taxed.

Basically, there are two instruments for taxing of emissions.[10] The first of these is to tax the quantity of carbon dioxide and other greenhouse gases like methane that are emitted. Although this fixes the “price” of carbon emitted, emissions as a whole may fluctuate. This gives corporations certainty about the costs of emissions, which benefits investment decisions aimed at reducing emissions. The government will, however, face some uncertainty about the extent to which emission reduction targets will be achieved. The alternative instrument is an emissions trading system whereby the government sets a ceiling for total emissions and under which corporations can buy marketable certificates for quantities of carbon emissions. This instrument puts a cap on maximum emissions, but carbon prices may fluctuate.[11] Fluctuating carbon prices may cause uncertainty among corporations, which may impede investment in green technologies.

10 Regulatory measures are the alternative for influencing behaviour through economic incentives, including price incentives. Examples of such measures are emissions standards, quotas on specific products, bans, etc. For an overview of possible climate policy instruments, see for instance Levinson and Shetty (1992).
11 Assuming that available emission allowances are scarce.

2.3 Current status of carbon taxation for the corporate sector

Compared with other countries, the direct tax rates on carbon emissions (through the ETS) in the Netherlands are relatively low. Including energy taxes, large corporations in the Netherlands pay less for their carbon emissions than their European counterparts, and less than smaller consumers and households. This means that the detrimental external effects of corporate sector carbon emissions are subject to limited taxation only, and large corporations are not yet paying the prices necessary to achieve the climate agreement objectives in due course.

Various countries levy tax on carbon emissions by means of direct methods. This may be done either by taxing emissions directly, or by means of emissions trading. Rates vary between EUR 6 (per tonne of carbon dioxide) in China and EUR 112 in Sweden (see Table 1).[12] The scope of the tax instrument depends on the local emissions covered by the instrument, and varies between less than 10% of local emissions in Spain and 70% or more in Norway and North America. The scope is primarily determined by the industry sectors that are subject to the tax. Emissions trading foreseen for China will for instance cover the energy sector only. In California on the other hand, the transport sector and the manufacturing industry are also subject to a local emissions trading scheme.

12 Table 1 lists a selection of countries, including those with the highest carbon tax rates, being Sweden, Switzerland, Finland, Norway and France. In May 2018, carbon emissions pricing systems were in place in 70 countries (taxation, emissions trading or both), covering 15% of worldwide greenhouse gas emissions. The number of schemes for direct carbon taxing came to 26, mainly active on a national level (World Bank, 2018).

20

The ETS is the only form of direct carbon taxing in the Netherlands. It covers industrial corporations, such as steel producers, refineries, chemicals companies, and power plants. Important other sources of emissions like the transport sector and the bulk of the agricultural sector are not subject to the ETS. Various European Member States, including France and the Scandinavian countries impose national carbon taxes in addition to the ETS, mostly on sectors that are not subject to the ETS. The United Kingdom taxes the ETS sectors by means of a minimum carbon dioxide price.

Indirect forms of carbon taxing mostly take the shape of energy taxation. In the Netherlands for instance, energy is taxed by means of taxes on electricity, gas and fuel excise duties. Basically, these energy taxes can be seen as a form of carbon taxing, in as far as fossil energy sources are concerned.[13] This makes the effective tax burden on carbon emissions higher than the direct carbon emissions taxation alone.

The OECD calculates the tax burden on all carbon emissions caused by energy consumption. In 2015, carbon taxation in the Netherlands came to around EUR 60 per tonne on average for households and corporations (OECD, 2018b). In France and the United Kingdom, more is paid on average per tonne of carbon emitted (EUR 80-90), less is paid in Germany (EUR 40), and far less in China and the United States (around EUR 10). Excluding the road transport sector, carbon taxing in most countries is way below the Dutch level of EUR 24 per tonne of carbon emitted, and corporations often pay less than households. According to OECD calculations, the manufacturing industry in the Netherlands pays EUR 15 per tonne. At EUR 10 per tonne,

13 That said, in addition to the detrimental effects of greenhouse gas emissions, there are other negative external effects at the root of these taxes, e.g. the deterioration of air quality and increasing traffic congestion.

Table 1 Direct carbon taxes, formally announced and introduced

Country or region	Instrument	Price (EUR/tonne of CO_2)	Scope (% of emissions)
Canada (various regions)	Emissions trading and carbon tax	16	40%-70%
China (various regions)	Emissions trading	6	30%-40%
Denmark	Carbon tax	23	40%-50%
European Union	Emissions trading	13	40%-50%
France	Carbon tax	44	30%-40%
Finland	Carbon tax	62	30%-40%
Ireland	Carbon tax	20	40%-50%
Iceland	Carbon tax	29	20%-30%
Liechtenstein	Carbon tax	81	20%-30%
Netherlands (EU)	Emissions trading	13	40%-50%
New Zealand	Emissions trading	12	50%
Norway	Carbon tax	52	60%-70%
Spain	Carbon tax	20	0%-10%
UK	Carbon tax	20	20%-30%
US (various states)	Emissions trading	12	60%-90%
Sweden	Carbon tax	112	40%-50%
Switzerland	Emissions trading and carbon tax	81	30%-40%

Source: World Bank, 2018.

electricity producers pay even less.[14] Owing to competitive considerations, industrial bulk consumers are often given exemptions and rebates on energy taxes, while small consumers pay far higher rates, both for gas and electricity. This discrepancy in tax rates is wide in the Netherlands.[15] According to Ecofys (2015), the Netherlands is the only country where highly energy-intensive corporations may be substantively exempt from electricity taxation, by being offered low tax rates and refund schemes. This means that these corporations on balance pay very little per tonne of carbon emitted.

14 A full complete breakdown between households and corporations is unavailable. The implicit tax rate for homes and commercial services together is EUR 100 per tonne, road transport implicitly pays EUR 250, and agriculture EUR 50.

15 Taxes on gas and electricity are both divided into five brackets.

3 Analytical framework for the impact of carbon taxing

In this and the next chapter, we will explore the economic impact of carbon taxing for the corporate sector. This chapter discusses the analytical framework, and Chapter 4 details our results. In the coming decades, greenhouse gas emissions must start to decline towards zero. Taxing corporate emissions may be the chosen policy to achieve this objective. It makes the social costs of carbon emissions visible, cleaner production will become more attractive, and investment in energy conservation will become more profitable. This may be captured by introducing a carbon emissions tax. An often heard objection to introducing carbon taxing is that it will initially lead to an undesirably strong increase in production costs, which in turn greatly reduces sales. Energy costs already constitute a huge cost item for some individual industry sectors, which have a strong overlap with the emission-intensive industry sectors. This means that a relatively strong impact of carbon taxing may be expected here, especially if carbon taxing is introduced in the Netherlands only. Based on the preceding chapters of this study, this will apply to energy companies, the transport sector, the agricultural sector, and the manufacturing industry. Within the manufacturing industry, the metals and chemical sectors are very emission-intensive. Due to the international variation in emissions between the different industrial sectors, the introduction of not only national, but also European carbon taxing, may be accompanied by a loss of international competitiveness for Dutch corporations. The manufacturing industry is particularly vulnerable to this as a relatively large proportion of products is traded internationally.

3.1 The main principles of the input-output model used

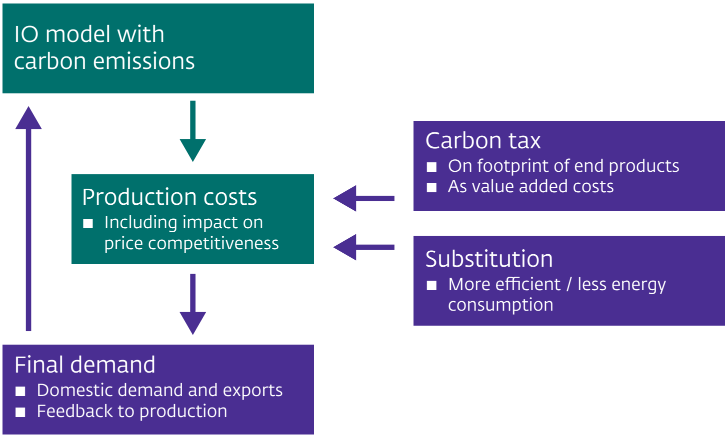
We used an input-output model (IO) model to calculate the impact of the introduction of a carbon tax for prices and sales per industry sector. This model includes quantitative data on intermediate sales and final demand of industry sectors and provides a detailed picture of the national and international interconnectedness between these sectors. Our analysis includes the input-output data of a large number of countries. This has also revealed the international connections between the industry sectors.[16] We made several adaptations to the customary version of a multiregional IO model.

We supplemented the IO data for the Netherlands with data on quantities and prices of labour, capital and energy that a given industrial sector uses to achieve its production.[17] The level of greenhouse gas emissions (denoted as carbon) for each industrial sector is also known.[18] Carbon emissions are related to the production levels achieved in each industry sector, which first of all consist of final products for national and international customers (final demand). In addition to final products, production also consists of intermediate sales used as input for other industry sectors. The output of the concrete industry for instance is largely destined as intermediate input for the construction sector. The IO tables allow us to allocate the carbon footprint of the concrete industry to the construction sector and to other final products like materials sold in DIY stores. In this way we can calculate the carbon footprint involved in the production of final products for each industry sector.

We then introduced a tax rate per quantity of carbon emitted (see Figure 6). With the help of the IO model and based on the total carbon footprint associated with the final products produced by an industry sector, we can directly calculate the resulting carbon tax amount. In this way, each industry sector is taxed for the carbon emissions caused in the entire preceding production chain. The tax amount due to be paid is added to the value added

16 Our calculations use the international EXIOBASE dataset, based on 2015 data (www.exiobase.eu; see Stadler et al., 2018; Tukker et al., 2013, and Wood et al., 2015).
17 Drawn from external statistics sources.
18 This was also taken from EXIOBASE. See also footnote 1.

Figure 6 Diagram of IO model (green) and additions (purple)



costs incurred by an industry sector and pushes up production costs. This is an alternative option as compared with the more frequently used method whereby carbon tax is implemented as an increase in the input prices of energy products.[19] As this is an international IO model, we can compare the impact of carbon taxing on the production costs of industry sectors in the Netherlands with those abroad. Based on the outcome, we can quantify the change in the price competitiveness of the entire Dutch economy relative to other countries.[20]

19 We prefer taxing of carbon emissions through value added. This is a more comprehensive approach as it includes all emissions, not only those associated with energy consumption, but also emissions related to production processes and emissions of other greenhouse gases. It is also more efficient as the emissions themselves are taxed rather than the use of a particular input (fossil fuel). See Fullerton (1996) for more details about both methods.

20 The annexes to this report include a full description of the methodology used (IO model, price and substitution effects, calculation, aggregated sales prices and competitiveness).

We expanded the results of the IO model for production *costs* by individual industry sector by adding the estimated impact on final demand, meaning the *quantity* of production for each industry sector. Cost increases due to carbon taxing translate into higher prices, which in turn influence final domestic and international demand (quantities sold). To bring this into focus, we used the price elasticity of consumption and exports for all individual industry sectors. The changes in final demand in the IO model translate back into the production of each industry sector (see section 4.3). In the next section, we will add substitution to the model, i.e. the transition to less energy-intensive production.

3.2 Substitution added to the IO model

The customary IO model assumes that carbon taxing directly and fully crystallises in production costs. Our model expansion means that we include the possibility of corporations taking a flexible approach to their energy consumption, thus partly counteracting cost increases.

An important assumption in IO models is that there is a fixed ratio between inputs and output. If production costs change, as they would when carbon taxing is introduced, corporations will likely want to adjust their production factor mix at any given time. Lower energy input will then be offset by other production factors, e.g. extra labour or new capital goods.[21] In practice, corporations replace machinery by more expensive, but more energy-efficient types. Other examples are investment in insulation of buildings, or moving to more energy-efficient premises. Such adjustments to achieve more energy-efficient production may have a dampening effect on the calculated cost increases resulting from carbon taxing. It is impossible to

21 For that matter, corporations may also decide to substitute one form of energy by another. Our study leaves this out of scope.

say beforehand how much time it will take corporations to adjust their production processes to more energy-efficient production. Adjustments may require investment or be blocked by long-term contracts. However, the calculated effects of the introduction of a carbon tax on production costs are expected to be smaller as corporations are better able to limit their energy consumption.

In order to take account of this factor substitution, we used a variable IO model. This means that the ratio between production factors may change following carbon taxing, but not necessarily to the same extent in every industry sector. In order to bring this into focus, we made econometric estimates of production functions for the Dutch industry sectors. These estimates can be used to quantify how the use of capital, labour and energy changes as a consequence of cost increases related to carbon taxation.[22] Hence, we considered the estimated substitution elasticities between energy on the one hand and capital goods and labour on the other.
The substitution options prove to be limited in virtually all industry sectors. The average estimated substitution elasticity is around 0.3, when a 1% rise in energy prices is accompanied by 0.3% more use of capital and labour. Recent studies confirm this.[23] This may be explained by energy and capital goods being highly complementary.[24] Once installed, capital goods require energy consumption that is very difficult to adjust in principle. The energy input can be reduced only after investment in new capital goods takes place.

22 Van der Werf (2008); see Annex 1 for our calculations and background information.
23 Annex 1 includes a more detailed comparison of our results with the current literature.
24 Kim and Heo (2013) base these conclusions on comparable research among ten OECD countries.

Modelling of factor substitution

The production technology of industry sectors can be simplified by means of a production function with capital (K), labour (L) and energy (E) as inputs and a coefficient τ for technological progress.

$$Q = F(K, L, E, \tau)$$

In this very general formulation, the quantities of capital, labour and energy can be adjusted unrestrictedly. In order to describe the technologies used by corporations or industry sectors, empirical research typically selects a particular specification for F. This can also be used to reflect to what extent the inputs are mutually substitutable in order to produce the same level of output. Well-known examples are the Leontief, Cobb-Douglas and CES functions. The parameters of these functions determine how a cost minimising corporation reacts to a price increase in one of the inputs. In a CES function, this substitution elasticity is constant, with value 1 in a Cobb-Douglas function and 0 in a Leontief function. This last function is analogous to the production technology in the IO model with fixed ratios between all inputs.

In our empirical specification, we have opted to use the CES function. A low econometric estimate of the substitution elasticity means that the input of capital in a given industry sector hardly responds to a price increase in energy. The IO model with fixed coefficients then is a reasonable approach of production technology.

A possible explanation for the low substitution elasticity (or complementarity) between energy and capital is that the use of capital goods is accompanied by adjustments costs. This means that it takes time to adjust the quantity of capital to new energy prices. An alternative explanation is that capital goods are less homogeneous than assumed in a theoretical production function. The available capital goods then vary, and can be combined with energy in various fixed ratios. Once installed, capital has a fixed energy consumption. It takes time for corporations to invest in new capital goods with lower energy intensity (see e.g. Atkeson and Kehoe, 1999).

3.3 Policy scenarios for carbon taxation

The first scenario for taxing emissions is the introduction of carbon taxing for all industry sectors in the Netherlands only. As we saw, Dutch corporations have a relatively high emission intensity while energy consumption does not deviate much from the European average. In addition, and contrary to some other European other countries, there is no direct carbon taxation in the Netherlands apart from the ETS. Even including energy taxes, large corporations in the Netherlands pay less for their carbon emissions than in other European countries. In the next chapter, we will calculate the economic effects for each industry sector for this first scenario. We will also show the effects of a less broadly implemented tax in the ETS sectors only, which also include the bulk of the energy sector. And we will show the effects of taxation of electricity producers only. This is in line with the 2016 coalition agreement, which proposed to introduce a minimum carbon price for electricity producers on top of the ETS. This would be a tax of EUR 18 per tonne in 2020, rising to EUR 43 in 2030.

We will then analyse an alternative scenario, which assumes that the same carbon tax is introduced across the EU (see section 4.4). There already is a European carbon tax in place, which is the ETS. A European tax on carbon emissions may therefore be implemented in the form of a minimum price within the ETS framework, and may or may not be broadened to more corporations or industry sectors. Coordinated policies to this effect on a European scale will, however, take a great deal of negotiating, and is slow in getting off the ground at this moment in time.

All our scenarios for carbon taxation calculate the economic effects *relative to the current situation*, with some form of carbon taxation already existing in many industry sectors. Our calculations are based on a tax of EUR 50 per tonne of carbon emitted (including other greenhouse gases, see footnote 1). So this tax is imposed on top of the existing taxes on energy and the carbon tax levied as part of the ETS.

Imposing an additional carbon tax of EUR 50 per tonne cannot be expected to achieve a full switch to a carbon-free economy in the longer term.[25] This rate should therefore be seen as a starting point for gradually increasing carbon pricing. That said, it is fairly simple to adjust the results of the calculations presented here to an alternative carbon tax rate.[26]

25 Poelhekke (2017) cites estimates for social costs of carbon emissions up to EUR 150 per tonne.
26 The underlying calculations are largely linear: the effects of (say) a twice as heavy levy are twice as large.

4 The impact of carbon taxation on the industrial sectors

This chapter depicts the results of the IO model upon the introduction of a carbon tax, initially in the Netherlands only. We will explore the effects on production costs, the international competitiveness, and demand for end products at the level of the individual industry sectors. Alternatively, we will show the model results upon the introduction of a European carbon tax.

4.1 Increasing production costs

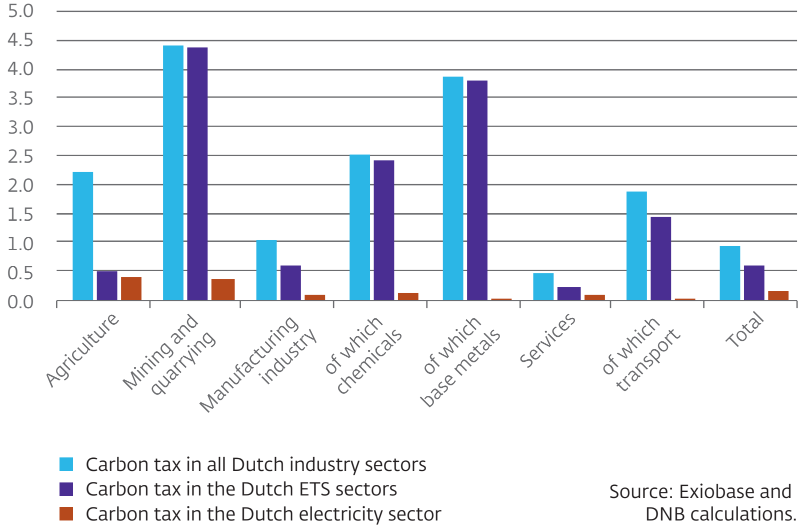
We will first examine the effects of an additional, direct carbon tax on production costs in the Netherlands. The assumed tax of EUR 50 per tonne of carbon applies to all corporations and all their emissions, including those that are part of their intermediary outputs. As said, this tax is imposed on top of the existing, indirect carbon taxation, like the energy tax and the ETS.

The largest emissions are caused by energy corporations, which will therefore see the sharpest rises in production costs: 11% on average. Coal generated electricity will be taxed in particular. A part of the emissions caused by energy producers will be taxed with corporations consuming energy. This largely consists of electricity. This will cause production costs to increase also in other industry sectors. These enterprises also use other raw materials or intermediary goods that cause carbon emissions. Our calculations reveal that the average cost increase remains limited to just 1% for the Dutch economy as a whole, but this masks large differences between individual sectors.

Figure 7 shows for each industry sector (excluding energy) the cost increases following from the assumed carbon tax levied on all Dutch enterprises. These cost increases were first calculated for each of the over 150 industry sub-sectors, and subsequently averaged per industry sector. By comparison, we will also show the results of two variants in which costs increase less significantly because the tax is levied on a smaller group of industry sectors.

Figure 7 Increase in production costs for Dutch enterprises caused by carbon tax in the Netherlands

Percentage changes; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

These are the ETS sectors and the electricity sector. For all industry sectors taken together, we will present a weighted average of the cost increases, using sales per sub-sector as the weight.[27]

The industry sectors causing the largest emissions also show the largest cost increases, i.e. mining and quarrying (4.4%) and base metals (3.9%). At between 1.9% and 2.5%, cost increases in the chemicals, agricultural and transport sectors are less significant, but still considerable. In the remaining industry sectors, cost increases are below 1%. On average for the Dutch

27 For reasons of calibration, the energy sector is not shown separately in Figure 7, and the same goes for Figures 9, 12, 13, 15 and 16.

economy as a whole (including energy), the cost increases amount to 0.9%. This is because for most enterprises energy, and carbon emissions with it, accounts for only a small percentage of total costs. In addition, mining and quarrying, chemicals and base metals have a small share in total production (almost 5% for the three sectors together).

In the other two variants, including a carbon tax in the ETS sectors or in the electricity sector only, the taxation effects on all sectors is somewhat reduced on average. In the tax under the ETS only, cost increases are smaller in services sector, including transport, and in the agricultural sector in particular. Cost increases, however, remain relatively large for mining and quarrying, chemicals and base metals, where the majority of the ETS enterprises are located. Taxation for electricity companies only will keep cost increases in all industry sectors limited to less than 0.5%. Cost increases for energy companies will not change much in both variants, remaining at 11% (not shown in the figures).

These calculations show that some industry sectors will be faced with sharp cost increases, even if the carbon tax does not apply to all enterprises, but to the ETS sectors only. The chemicals and base metals industries will see their costs rise by 2.5% and almost 4% respectively in these two scenarios. In addition, these percentages may differ sharply between individual enterprises, among other things depending on the level of their carbon footprint.

4.2 Deterioration of international competitiveness

A higher carbon tax for the Dutch corporate sector will impact the international competitiveness of exporting enterprises. They compete on various aspects, including sales prices, predominantly reflecting production costs. This section considers the production costs of Dutch exports, set against those of other countries, as a measure of price competitiveness, both for the economy as a whole and for the individual industry sectors.[28] While we present our results for seven or eight industry sectors, our calculations distinguish well over 160 product groups. An industry sector's export mix is usually not identical to its domestic sales mix. As a result, an industry sector's average cost of exports may differ from the average cost of its overall sales, i.e. domestic sales plus exports. The same applies to the emission intensity of domestic sales and exports, so that the impact of carbon tax can also differ between domestic sales and exports.

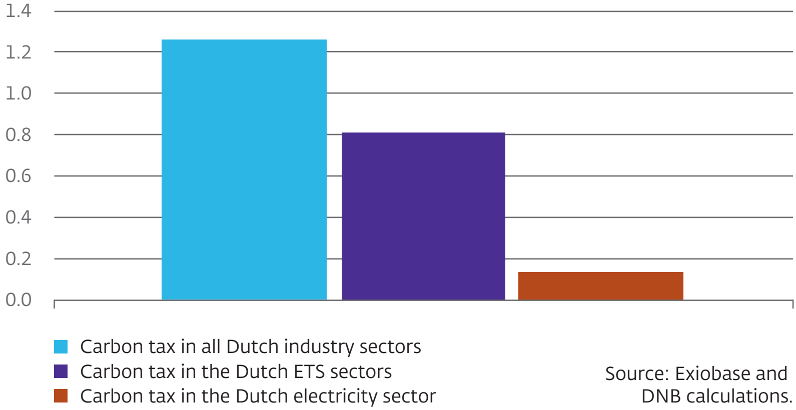
In the case of a carbon tax in all Dutch industry sectors, the average cost price of Dutch export products rises by 1.2% relative to other countries (see Figure 8).[29] The effects are smaller in the other two variants: the introduction of a carbon tax has negative effects of 0.8% and 0.1%, respectively for the ETS sector and for electricity companies. The modest effect on the macroeconomic level, however, hides the fact that large differences are visible between the industry sectors (see Figure 9). This is consistent with the increase in production costs calculated in the preceding section (as shown in Figure 7).

The Netherlands' competitiveness deteriorates the most in the mining and quarrying (4.3%) and chemicals (3.0%) industry sectors, which export a large part of their production. In transport and agriculture competitiveness will also deteriorate by more than 2%. In base metals the effect of a carbon tax on competitiveness is less unfavourable than would be expected based on the cost increases: export prices will rise by 1.4% relative to foreign countries, while production costs increase by 3.9%. The reason is that exports in this industry sector are less carbon-intensive than production. If a carbon tax

28 Relative export price indices as used take account of the export mix of each industry sector and country. The export prices of other countries are weighed against bilateral exports from the Netherlands, see Annex 2.
29 The introduction of a carbon tax in the Netherlands has a modest effect on foreign export prices through the intermediary deliveries made by Dutch to foreign producers.

Figure 8 Deterioration of Dutch competitiveness (+) caused by carbon tax in the Netherlands

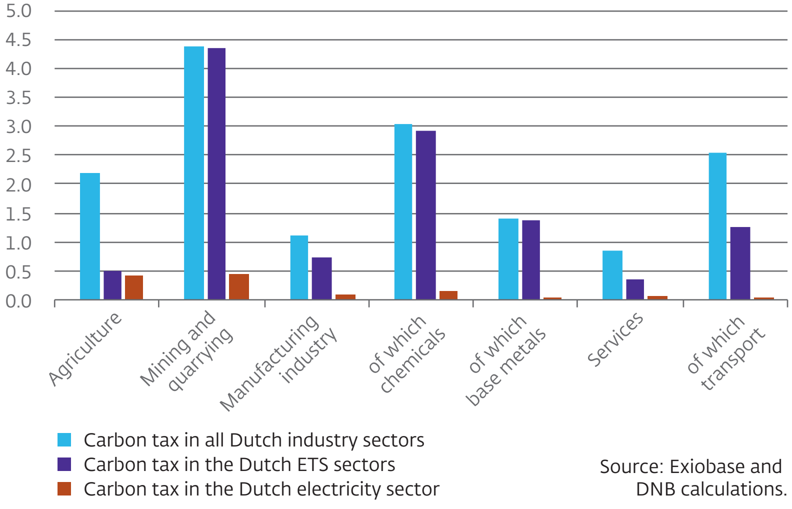
Percentage change in production costs of Dutch exports compared to other countries; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

Figure 9 Deterioration of Dutch competitiveness (+) by industry sector caused by carbon tax in the Netherlands

Percentage change in production costs of Dutch exports compared to other countries; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

were to be introduced in the ETS sectors only, agriculture would stand to benefit the most, with export prices rising by 0.4% rather than 2.1%. Although agriculture has a heavy carbon footprint, it is not subject to the ETS.

4.3 Declining sales

The impact of a carbon tax on sales of final products depends on the degree to which the price increases calculated above push up market prices at home and abroad. In order to estimate this, we will assume that a rise in production costs is fully passed on into the sales price of final products. This is the case with perfectly elastic supply, as is reflected in the flat supply curve shown in Figure 10. Among other situations, this is the case if all industry sectors have a market form with perfect competition.[30] As this assumption applies less, the calculated quantity reduction will become smaller.[31] In other words, the sales declines calculated here represent the upper bound of the anticipated sales effects.[32]

The demand side of the market also plays a role. Suppliers have more options of passing costs on to their sales prices if buyers are less sensitive to price increases. Sales will only fall slightly then. Conversely, sales may fall sharply if buyers are sensitive to price increases. The decline of sales towards the new market equilibrium upon a small price increase is relatively large in this case.[33] This depends on the sectoral price elasticities of demand. These indicate for each industry sector the percentage at which demand falls in

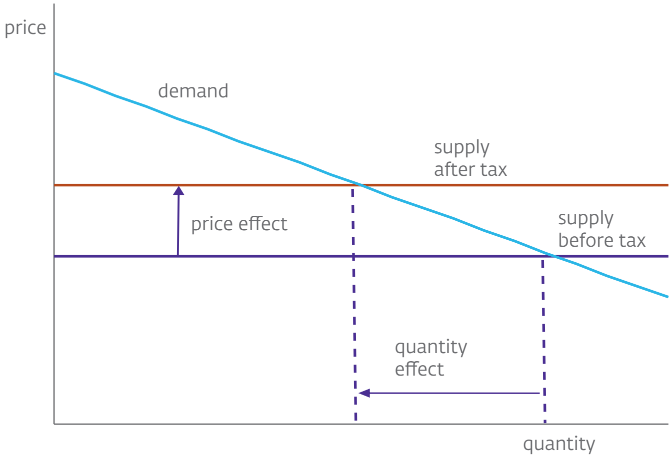
30 The carbon tax on final products can be seen as an *ad valorem* tax. As we have insufficient information on how supply reacts to this cost increase, we will assume that the cost of the carbon tax is fully passed on into sales prices, or that the price elasticity of supply is (infinitely) high. Theoretically speaking, this is the case with perfect competition amid constant returns to scale.

31 This depends on factors outside of the range of this study, e.g. market conditions. That said, we will also refrain from including other macroeconomic effects of higher production costs, e.g. on inflation, employment, and international trade.

32 Figure 10 can also be read as an equilibrium situation in a market with perfect competition, where entry and exit of enterprises ensures that market prices are equal to average costs (Varian, 1984).

33 As this is a study at industry sector level, we will refrain from including the macroeconomic feed-through effect of the tax revenues, by way of extra government income. See also chapter 5.

Figure 10 Effect of higher production costs with price elastic demand



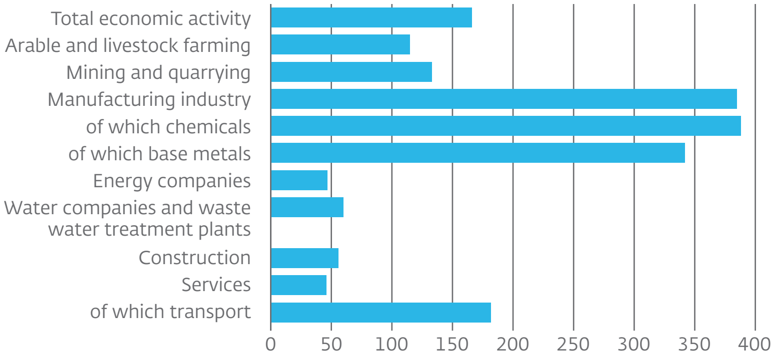
case of a price increase. Figure 10 reflects this in the slope of the demand curve. Our calculations are based on the elasticities used in Smid et al. (2006).[34] In our calculations, we distinguish between export demand and domestic demand.[35] Domestic demand of the transport and catering sectors for instance is price elastic (-2), against the on average fairly inelastic demand for services (-0.3), mining and quarrying (-0.3), and the manufacturing industry (-0.4).

34 In as far as this was available, we awarded a demand elasticity to each industry sub-sector on a two-digit level. Annex 2 has a full overview of the elasticities used.

35 In the IO model, final demand consists of domestic and foreign demand. Both react to price movements based on separate values for demand elasticity. With the help of the IO model, the adjusted final demand was translated into the production of each industry sector (see Annex 2).

Figure 11 Openness of Dutch industry sectors

Sum of imports and exports as a percentage of gross value added, 2016



Source: Statistics Netherlands, National Accounts 2017.

Economic studies show that export demand is typically more elastic than domestic demand. The elasticities that we applied for each industry sector are between -1 and -2. Export demand in the chemicals and metals industries have the highest elasticity (-2). Foreign buyers of these products may relatively easily switch to competitors in case of price rises. This is primarily explained by the higher degree of competition in these industry sectors (Babiker, 2005; Reinaud, 2008). An indication of competitive sensitivity is the level of openness displayed by industry sectors (see Figure 11). The manufacturing industry, including chemicals and base metals, has a large degree of openness.

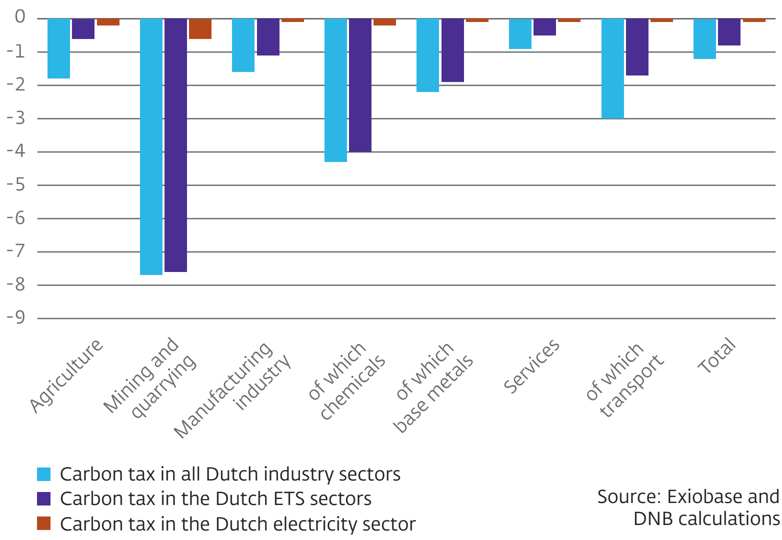
Based on price elasticities, Figure 12 shows the extent of anticipated declines of sales for each industry sector, given the calculated rise of production costs. The biggest effect is seen in mining and quarrying, a carbon-intensive industry sector in which costs are set to increase sharply and competitiveness will deteriorate most (Figure 9).

After mining and quarrying, sales will decline most in chemicals, shrinking by 4.3%, followed by transport (-3.0%) and base metals (-2.2%). Sales will decline less sharply in agriculture (-1.8%) and services (-0.9%).

For the economy as a whole, sales are anticipated to fall 1.2% if the carbon tax applies to all industry sectors in the Netherlands. If the carbon tax is levied in the ETS sectors only, the drop amounts to 0.8%, and if the electricity sector only is taxed, sales are anticipated to fall 0.1%.

Figure 12 Change in sales of Dutch enterprises caused by carbon tax in the Netherlands

Percentage changes; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

4.4 Effects of a European carbon tax

From the perspective of climate policy – reducing worldwide carbon emissions – it is essentially a good thing if more countries start introducing carbon taxes. From a Dutch perspective, this may have the additional advantage of reducing the competitive disadvantage for the Dutch corporate sector. Obviously, if carbon taxation is introduced in more countries, the differences in cost price are expected to be smaller, and export prices will in part develop in the same direction. Generally, the coordinated introduction of carbon taxation can serve to mitigate the risk of carbon leakage, which refers to a scenario in which cost differences increase to such an extent that enterprises move their operations abroad, with emissions remaining equal or increasing. Likewise, domestic production may be replaced by imports that have higher emission intensities.[36]

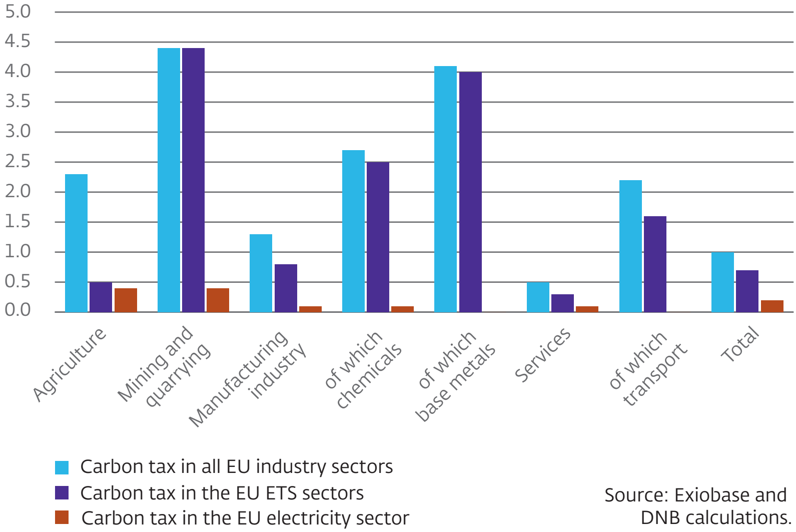
If a European carbon tax is introduced, our IO model calculations show that production costs of Dutch enterprises will increase more than if the tax were to be introduced in the Netherlands only. Competitiveness would still deteriorate, but markedly less than in the case of carbon taxes in the Netherlands only.

The fact that production costs of Dutch enterprises increase more sharply is attributable to the fact that in the case of a European carbon tax, enterprises will not only see their domestic costs increase, but also those of imported intermediary inputs. In this case, too, there are sharp differences between individual industry sectors (see Figure 13). In the transport sector, costs will increase from 1.9% in the case of a Dutch carbon tax, and 2.2% in the case of

36 The extent to which this “waterbed effect” occurs most likely depends on more factors than cost differences caused by emissions tax alone. Accordingly, little or no evidence of this effect has been found. Arlinghaus (2015), Partnership for Market Readiness (2015) and others provide overviews of the various empirical studies.

Figure 13 Increase in production costs for Dutch enterprises caused by carbon tax in the European Union

Percentage changes; EUR 50/tonne carbon tax



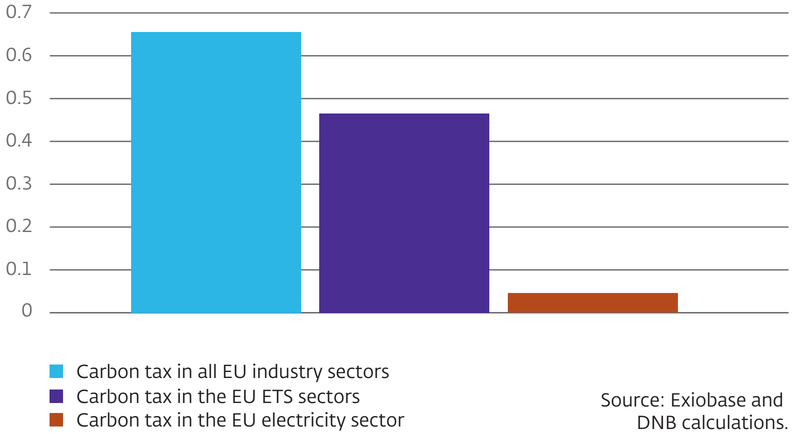
Source: Exiobase and DNB calculations.

a European carbon tax. In the manufacturing industry the cost increase will rise from 1.0% to 1.3%. In the services, agricultural and mining and quarrying sectors, the difference between a Dutch and a European carbon tax is negligible, as these sectors make far less use of intermediate products from the EU. Also, in general Dutch industry sectors are more interconnected with other domestic industry sectors than with foreign ones.

The average competitiveness of Dutch enterprises would deteriorate by 0.6% in the case of a European carbon tax (see Figure 14). This is a considerably less severe deterioration than with a Dutch tax only (1.2%). The fact that Dutch competitiveness would still deteriorate if a European carbon tax were introduced, is first of all due to the fact that production

Figure 14 Deterioration of Dutch competitiveness (+) caused by carbon tax in the European Union

Percentage change in production costs of Dutch exports compared to other countries; EUR 50/tonne carbon tax



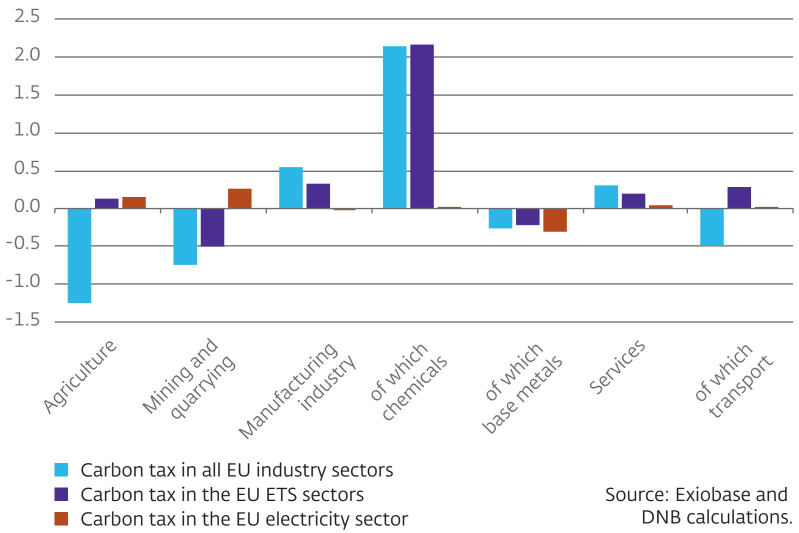
Source: Exiobase and DNB calculations.

costs in countries outside the EU would hardly increase. The Dutch export product mix also differs from that of other countries, meaning that the emission intensity of the export goods also differs. This is why the introduction of a European carbon tax on balance has a more pronounced effect on the production costs of Dutch exports than on those of trading partners. Export costs would for instance increase by 1.5% in the Netherlands and 1.1% in the UK, with an identical carbon tax.

Again, there are large differences between industry sectors. Figure 15 shows the increase in export prices relative to those of other countries, in the case of a European carbon tax. The chemical industry's competitiveness still deteriorates, although less markedly than in the case of Dutch carbon tax only (cf. Figure 9). This industry sector would be at a disadvantage in

Figure 15 Deterioration of Dutch competitiveness (+) by industry sector caused by carbon tax in the European Union

Percentage change in production costs of Dutch exports compared to other countries; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

the case of a European carbon tax, given that its export products are more carbon intensive than those in other countries. A European carbon tax may on the other hand have a positive impact on the competitiveness of the other industry sectors. Competitiveness of the Dutch agriculture, mining and quarrying, base metals and transport sectors would improve. For the agricultural sector, this is primarily due to the lower emission intensity of its exports as compared to peers in the rest of the EU. The improvement in mining and quarrying is related to the relatively high share of natural gas, which has a lower carbon intensity than coal. In Germany for instance, which accounts for 44% of Dutch mining and quarrying exports, the share

44

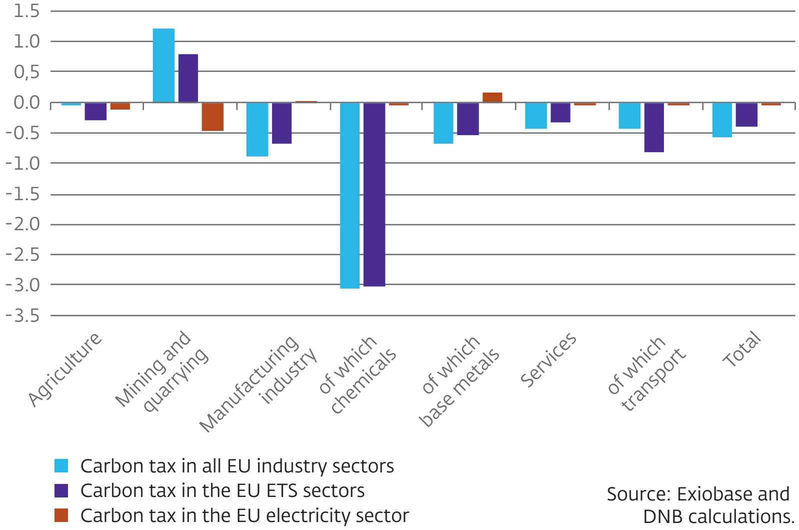
of coal is much larger. A European carbon tax would therefore cause a stronger cost increase in Germany than in the Netherlands. In base metals and transport the improvement of competitiveness upon the introduction of a carbon tax in the EU is also accounted for by the relatively lower emission intensity of export products relative to trading partners.

Next, we consider the effect of higher production costs on sales, both domestic and to other countries. On balance, sales of all Dutch industry sectors will drop after the introduction of a European carbon tax. The total shrinkage of the volume of production across all industry sectors is 0.6%. This is less than would occur if a carbon tax were introduced in the Netherlands only (1.2% shrinkage). At the level of individual industry sectors, the differences relative to Dutch-only taxes are more pronounced, especially in agriculture, where production remains unchanged, and in mining and quarrying (see Figure 16). Production could increase by 1.2%, whereas carbon taxation in the Netherlands only would cause a 7.7% drop.

In itself, it makes sense that European policies would have a less negative impact on production than Dutch domestic policies. The difference is primarily caused by exports, as the Dutch competitiveness would deteriorate far less in the event of European policies. It is too early, however, to conclude that European carbon taxation would be more favourable for the Dutch economy across the board than carbon taxation in the Netherlands only. Sales to other countries not only depend on export prices, but also on export demand. Upon the introduction of a European carbon tax, domestic demand would also decline in other countries. This has a dampening effect on world trade with an extra negative impact on the Dutch economy. We have not modelled this second round effect.

Figure 16 Change in sales of Dutch enterprises caused by carbon tax in the European Union

Percentage changes; EUR 50/tonne carbon tax



Source: Exiobase and DNB calculations.

4.5 Summary: impact according to the IO model

In this chapter, we calculated the impact of an additional carbon tax, at EUR 50 per tonne of CO_2 equivalent, using the IO model. Table 2 summarises our model results for production costs, competitiveness and sales. We show six variants (columns) for the scopes of the carbon tax. The “heaviest” variant represents a tax on the whole economy in the Netherlands only (first column). On average, the impact seems to suggest that not much harm is done. Zooming in on the individual sectors of industry, however, we see large differences. For example, sales in mining and quarrying decline by 7.7%. The chemicals and transport sectors also suffer significant production losses.

Overall, the adverse economic impact is less pronounced if a carbon tax is levied across the European Union or if its scope is limited to specific industry sectors. Even then, however, the differences between the individual industry sectors will still be significant in some cases. Sales of the Dutch chemicals industry will for instance still fall sharply in the case of a European carbon tax. This shows the importance of a sectoral analysis. We will supplement this in the next chapter by taking a closer look at the macroeconomic consequences.

Table 2 Summary: impact of carbon tax on Dutch enterprises

Percentage change; based on IO model

	Carbon tax in the Netherlands			Carbon tax in the European Union		
	entire economy	ETS sectors	electricity-sector	entire economy	ETS sectors	electricity-sector
Production costs						
average	0.9	0.6	0.1	1.0	0.7	0.2
minimum	0.5	0.2	0.0	0.5	0.3	0.0
maximum	4.4	4.4	0.4	4.4	4.4	0.4
Loss of competitiveness						
average	1.2	0.8	0.1	0.6	0.4	0.0
minimum	0.8	0.3	0.0	-1.3	-0.5	-0.3
maximum	4.3	4.3	0.4	2.1	2.2	0.3
Sales						
average	-1.2	-0.8	-0.1	-0.6	-0.4	-0.1
minimum	-7.7	-7.6	-0.6	-3.1	-3.0	-0.5
maximum	-0.9	-0.5	-0.1	1.2	0.8	0.2

5 The macroeconomic impact of carbon taxation

In this chapter we will use a macroeconomic model to estimate the impact of carbon taxation. This allows us to take account of the broader pass-through effect of the carbon tax on income, spending, wages and inflation. Our projections are for several years ahead, so they do not cover the longer term when corporations start reducing their emissions with fundamental adjustments, as a result of the introduction of the carbon tax.

For the economy as a whole, we find no major impact. An immediate and widely-scoped EUR 50 increase in carbon tax will reduce GDP by almost 1%. The macro model also allows us to explore the options for the use of the carbon tax revenues received by the government. Given the characteristics of the model, we can only show this for generic policy measures, e.g. a reduction in corporate or private income taxes. Most likely, however, it is more effective to use the revenues in more specific measures, aimed at emissions reduction in the industry sectors most affected by the carbon tax. The quality of such measures will be discussed in the closing paragraph of this chapter.

5.1 Carbon taxation reduces GDP

In the preceding chapter, we calculated the extent of the rise in production costs in individual industry sectors as a result of the introduction of a carbon tax. The impact of such higher costs on prices and sales were estimated on the basis of elasticities, assuming that enterprises would pass on their costs in full. That assumption, which is necessary, implies that the outcome of the IO model represents a worst case scenario for the sales figures of industry sectors. In this chapter, we do not make such restrictive assumptions, but this means we can no longer distinguish between individual industry sectors.

We simulate the impact of an isolated increase in carbon tax in the Netherlands only, using DELFI, our macroeconomic model for the Netherlands (Berben et al., 2018).[37] In the model, the carbon tax feeds through in the form of an increase in energy costs and indirect taxes. Initially, the extra tax revenues are not used to introduce a compensatory tax cut, but add to the public finances.[38] According to the macro model, this will increase corporate sector production costs by 0.9%, in line with the IO model results (see section 4.1). Through higher prices, this adversely impacts real expenditure, such as consumption, investment and exports (see first column of Table 3). Unemployment comes out 0.6 percentage point lower, while real disposable household income ends 2.5% lower. All in all, GDP is dampened by 0.9%, which is less negative than the impact on total corporate sales calculated with the IO model of -1.2%.[39] The other two scenarios presented in Table 3 will be discussed in the next section.

5.2 Generic use of tax revenues

In all scenarios, both in the IO model and in the macroeconomic models, we assumed that the tax revenues generated signify a loss for the corporate sector and are not recycled into the economy. In order to bring into full focus the impact of a carbon tax, supplementary assumptions can be made about the government's spending of the additional tax revenues.

In principle, making careful considerations would require looking beyond the five-year impact that we present in Table 3. Energy transition encompasses a longer period of time and stands to benefit from specific technological innovation in order to work towards a carbon-neutral economy. The government could play a role here, using a part of the carbon tax revenues.

37 Annex 3 has a full description of the calculations made with DELFI.
38 In Ireland, for example, carbon tax revenues were used to bring down national debt levels in 2010, which had risen sharply in the aftermath of the financial crisis.
39 This is the outcome after five years, when the impact is at its peak.

Table 3 Macroeconomic impact of carbon taxation

Cumulative impact after five years; EUR 50/tonne carbon tax

	Use of additional tax revenues		
	improving budget balance	lowering income tax	lowering corporate tax
Gross domestic product (% change)	-0.9	0.5	-0.4
Real disposable household income (% change)	-2.5	1.8	-1.9
Private consumption (% change)	-2.1	2.2	-1.6
Business investment (% change)	-2.0	-0.5	3.4
Exports of goods and services (% change)	-0.5	-0.5	-0.1
Unemployment (% of labour force)	0.6	-0.4	0.3
Budget balance (% of GDP)	0.6	0.3	-0.4

The full results of such policies will only show in the longer term. The analytical tools currently at our disposal do not allow us to fully compute the impact of such use of tax revenues, but section 5.3 presents a qualitative discussion. Here, we quantify two general options, which are lowering income taxes and cutting corporate taxes.[40]

Lowering income tax will increase disposable household income, pushing up private consumption by 2.2% (second column in Table 3). In addition, production of companies increases and unemployment falls. Compared with the first scenario, in which there is no tax reduction, investment contracts to a lesser extent. The deterioration in competitiveness still depresses exports, but additional household expenditure offers ample compensation. On balance, therefore, GDP improves by 0.5%.

40 These policies are revenue neutral, meaning that additional revenues are fully used to cut taxes.

The second option for using carbon tax revenues is cutting corporate taxes overall. This boosts corporate investment as the cost of capital is lower (final column in Table 3). In itself, this has an upward effect on GDP. At the same time, however, labour has become relatively expensive for enterprises, causing unemployment to rise. This depresses household income, dampening expenditure. In addition, exports shrink due to deteriorated competitiveness. On balance, GDP is 0.4% lower. This means the adverse macroeconomic impact of carbon tax is smaller than in a scenario in which the government does not return tax revenues into the economy (first column in Table 3).

5.3 Options for specific policy

There are various options for returning carbon tax revenues specifically to the most emission-intensive industry sectors, like energy, chemicals and base metals. One way that will be attractive for enterprises is providing a temporary or gradually declining tax relief on the carbon tax due. For example, energy-intensive enterprises in the United Kingdom and California benefit from such a mechanism. In the Netherlands, too, energy-intensive enterprises may qualify for a discount on their energy bills to compensate for cost increases due to the ETS. The principal drawback of a rebate system is that it relieves the financial burden of enterprises, but also reduces the effectiveness of the instrument designed to achieve lower carbon emissions. For this reason, rebates in California are set on the basis of an enterprise's energy efficiency set against a benchmark. This keeps the incentive for further reduction in place. This does not alter the fact, however, that a carbon tax relief lessens the incentive for making operations more sustainable.[41]

41 See for example Fischer et al. (2012) and Partnership for Market Readiness (2017).

Most likely, it is more effective to return carbon tax revenues to the industry sectors most affected by the tax, provided they use them to develop cleaner technologies. Such a policy would not only tax emissions, but also reward desirable actions where possible. This works two ways, and it will also preserve economic activity that is important for the Netherlands. It will also help prevent corporate cost differentials to widen to such an extent that emissions "leak away" as relatively emission-efficient Dutch producers lose market share to more polluting competitors abroad.[42]

This type of tax recycling could be done by subsidising the development of sustainable technologies. One could think of an innovation fund, earmarked for specific initiatives for emission reduction, which would otherwise not get off the ground. In the chemicals and base metals sectors, this is the case for the further development of carbon capture and storage (CCS). After all, achieving the national reduction objective for carbon emissions in the Netherlands (95% in 2050) is hardly feasible without the large-scale use of CCS (PBL, 2017b). The manufacturing industry will also benefit from more research into the options for the use of hydrogen as an energy carrier, including its production and distribution.

Today, various governments are already putting the revenues of their carbon taxes to use as investments in renewable energy, in some cases through innovation funds. Such investments typically target more industry sectors than the energy-intensive energy sector alone. For example, in California, revenues are allocated to a fund for climate adaptation and mitigation, part of which is used to finance sustainable innovation. Australia uses around 40% of its carbon tax revenues to finance a fund aimed at transitioning towards climate-neutral production. Likewise, Denmark allocates 40% to

42 In this way, recycling tax revenues to the industry sectors most affected can help reduce potential "waterbed" effects. See also Partnership for Market Readiness (2017).

environmental and climate-related measures. In Japan and India, revenues go to a fund that finances renewable energy projects, climate adaptation and research into clean energy technologies.

An alternative option would be to set up a bonus-malus system for emission-intensive industry sectors. This would allow for rewarding of enterprises that outperform a predetermined criterion by means of subsidies. Companies that underperform the criterion in terms of pollution would not receive the subsidy or would be taxed more heavily. A benchmark of this kind already exists for enterprises covered by the ETS, which would make launching a bonus-malus system for emission-intensive enterprises fairly easy to do.

Lastly, providing subsidies to reward sustainable innovation, combined with imposing a carbon tax, has a solid economic underpinning.[43] Production costs have significant impact on the direction in which innovation is undertaken.[44] In particular, carbon taxation prompts enterprises to develop new production technologies with reduced carbon emissions.[45] This does require the carbon tax to be significant enough, however, to enable substantial investment in such innovations. Carbon pricing in itself is insufficient to achieve the optimum level of innovations that improve sustainability. Acemoglu et al. (2012) for instance show that the optimal policy to reduce carbon emissions theoretically consists of a combination of carbon taxation and subsidies on green innovations. By stimulating innovations, the manufacturing industry will over time succeed in reducing its carbon emissions, which would in turn reduce the impact of the carbon tax on production costs.

43 Generally, even without any carbon taxation, additional support during the initial stages of new technologies will be welcome, as enterprises often benefit insufficiently themselves from the expertise they develop, because it is in the public domain.
44 This is a complementary effect to the factor substitution introduced in section 3.2, consisting here of the impact of relative input prices on technological progress.
45 See for instance Newell et al. (1999) and Popp (2002).

6 Conclusions

Dutch enterprises emit large quantities of greenhouse gases compared to their foreign peers. This is related to the high proportion of fossil energy in the energy mix and specialisations in emission-intensive and highly emission-intensive products. An efficient way of reducing harmful emissions is to assign a price to the external effects of emissions. From an international perspective, Dutch corporations are still paying relatively little for their emissions. A higher and more broadly applied carbon tax will address the problem at the root and will function as a direct incentive for corporations to reduce their emissions and the attached social costs.

Our main conclusions are:

- For the economy as a whole, increasing emission taxes by EUR 50 per tonne proves not to have a major impact; GDP is depressed by roughly 1% after five years.
- The emission tax would, however, have a profound impact on a number of carbon-intensive industry sectors. The largest cost increases would occur in the chemicals, base metals, mining and quarrying, and energy sectors, resulting in significant deterioration of their international competitiveness.
- Overall, the adverse economic impact is much less pronounced when a carbon tax is levied across the European Union. Even then, however, the differences between the individual industry sectors will still be significant in some cases. Sales of the Dutch chemicals industry may for instance still fall sharply in the case of a European carbon tax.

- The wider macroeconomic effects of a carbon tax are to a large extent determined by how the government uses the additional tax revenues. Lowering income tax could relieve the burden of adjustment that households face.
- Alternatively, carbon tax revenues could be recycled by reducing corporate income tax overall. Most likely, however, it is more effective to use financial incentives to encourage the transition to clean technologies in specific industry sectors.
- Carbon tax revenues may for instance be used to set up an innovation fund targeted at developing more energy-efficient and less emission-intensive production technologies.

Annexes

The following background information is available on DNB's website:

1 Empirical research into sectoral production functions:
Notes on the estimation of substitution elasticities with three inputs

2 The applied input-output model:
The economic impact of pricing CO_2 emissions: input-output analysis of sectoral and regional effects

3 Macroeconomic scenarios:
The macroeconomic effects of a carbon tax in the Netherlands

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