norden

Carbon leakage from a Nordic perspective

norden

Carbon leakage from a Nordic perspective

Sigurd Næss-Schmidt, Martin Bo Hansen and Jens Sand Kirk,
Copenhagen Economics

TemaNord 2012:502

Carbon leakage from a Nordic perspective

Sigurd Næss-Schmidt, Martin Bo Hansen and Jens Sand Kirk,
Copenhagen Economics

TemaNord 2012:502
ISBN 978-92-893-2305-5
http://dx.doi.org/10.6027/TN2012-502

Print: Kailow Express ApS
Cover photo: Dansk Kulturarv/25 fantastiske
Copies: 230

Printed in Denmark

This publication has been published with financial support by the Nordic Council of Ministers. But the contents of this publication do not necessarily reflect the views, policies or recommendations of the Nordic Council of Ministers.

Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and Faroe Islands, Greenland, and Åland.

Nordic co-operation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic co-operation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

Nordic Council of Ministers
Ved Stranden 18
DK-1061 København K
Phone (+45) 3396 0200

www.norden.org

norden

Carbon leakage from a nordic perspective

Sigurd Næss-Schmidt, Martin Bo Hansen and Jens Sand Kirk, Copenhagen Economics

TemaNord 2012:502

Carbon leakage from a nordic perspective

Sigurd Næss-Schmidt, Martin Bo Hansen and Jens Sand Kirk,
Copenhagen Economics

TemaNord 2012:502
ISBN 978-92-893-2305-5

Print: Kailow Express ApS
Cover photo: Dansk Kulturarv/25 fantastiske
Copies: 230

Printed in Denmark

This publication has been published with financial support by the Nordic Council of Ministers. But the contents of this publication do not necessarily reflect the views, policies or recommendations of the Nordic Council of Ministers.

Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and Faroe Islands, Greenland, and Åland.

Nordic co-operation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic co-operation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

Nordic Council of Ministers
Ved Stranden 18
DK-1061 København K
Phone (+45) 3396 0200

www.norden.org

Content

Preface

Increasing the price of emitting CO_2 into the atmosphere is a forceful instrument. At the EU level, this is pursued through the common Emission Trading Scheme (ETS). At the national level, the ETS price is complemented by other implicit prices on CO_2 such as taxes on energy consumption and levies on electricity to finance renewable energy investments.

Such climate related policies are designed to reduce emissions by increasing the cost of energy intensive products and thereby lowering the demand for energy intensive products, and spurring more energy efficient innovations. However, in a globalised world with decreasing transport costs, foreign competitors from regions with less strict climate policies stand ready to serve the market with cheaper products. This means that domestic production, and the corresponding CO_2 emissions, is of the risk of moving abroad as a response to higher cost of energy, either through decisions to moving production facilities abroad or simply by being outmatched and forced to close production. The phenomenon that domestic CO_2 reductions may be offset by increased CO_2 emissions abroad is known as *carbon leakage*.

The Nordic Council of Ministers have commissioned Copenhagen Economics to assess the Nordic industries that are the most exposed to carbon leakage, and evaluate the characteristics of different instruments that could deal with the risk of carbon leakage. The analysis finds that leakage risks are very tangible and should be taken seriously. A specific area of interest to Nordic policy makers should be how to compensate energy intensive electricity consumers exposed to leakage risks. The analysis has been carried out during the period August 2011 – December 2011. The authors have been:

- Partner, Sigurd Næss-Schmidt, Copenhagen Economics
- Economist, Martin Bo Hansen, Copenhagen Economics
- Economist, Jens Sand Kirk, Copenhagen Economics

Copenhagen, 2 December 2011

Halldór Ásgrímsson
Secretary General
Nordic Council of Ministers

Summary

Setting a price on CO_2 is generally considered a highly effective tool to reduce carbon emissions and achieve abatement targets in climate policies. By raising the cost of emitting CO_2, it provides incentives for user and producers of fossil fuels to reduce consumption and develop low carbon products and processes.

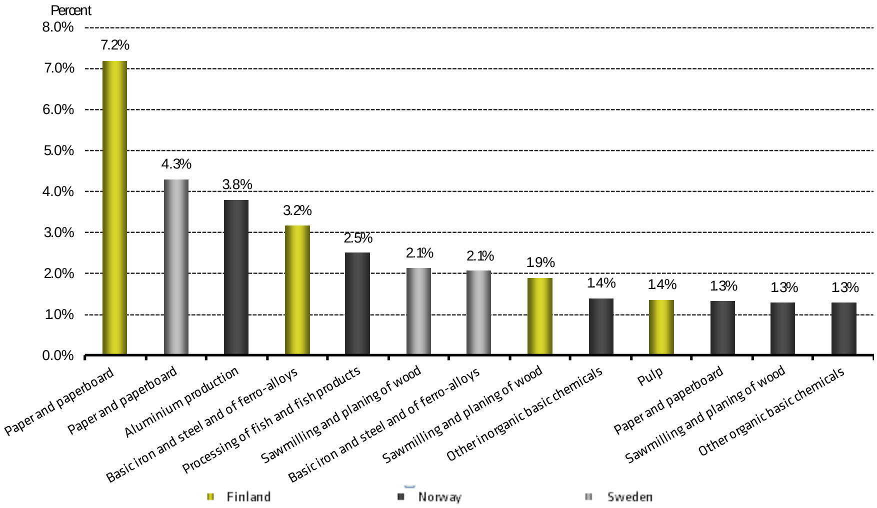
However, putting a price on CO_2 is also recognised as leading to carbon leakage: i.e. carbon emissions outside the region pursuing carbon policies may increase as firms inside the region lose competiveness due to higher energy prices. In this context, carbon leakage expresses how much carbon emissions increase outside the carbon policy region as a per cent of the abatement that is achieved within the region. A leakage per cent of 100 implies that the specific carbon policy regime is completely futile, since every unit of domestic abatement is followed by an equal rise outside the region.

This report identifies the 25 most leakage exposed industries in the Nordic area. The identification of these industries is based upon a number of leakage drivers and brakes. Drivers are characteristics that lead to carbon leakage. Such drivers are intensive energy consumption, high energy efficiency relative to competitors outside the region, and/or the existence of processes within the industry that are easy to split up and produce in other countries. While intensive energy consumption and the possibility for splitting up processes will drive leakage by increasing pressure to produce abroad, high energy efficiency within the region will drive carbon leakage through the fact that emissions will increase pr. unit of production if production is moved abroad. A classical example is the energy intensive production of clinkers related to cement production. Brakes are characteristics that somewhat "protects" an energy intensive industry from competition from countries with lower energy costs; at least temporarily. These brakes are high transportation costs per unit of value, high degree of product differentiation, limited transportability, and more policy related trade barriers (tariffs, exchange rate risks). In addition, a high level of capital intensity may imply that a producer has a substantial existing production capacity which will be used until it is run down: this will slow down the leakage process.

It is primarily sectors related to the paper and pulp industry (paper and paperboard, sawmilling, and pulp), iron and steel, aluminium, processing of fish, and manufacture of chemicals that are determined to be at risk of carbon leakage in the Nordic countries. These key leakage exposed industries account for between 1.6 per cent and 14.6 per cent of

value added in the Nordic countries, with Denmark at the lowest end and Finland at the top end. Out of total Nordic value added, these industries account for 10.2 per cent. The economically most important leakage exposed industries are paper and paperboard, aluminium and iron and steel production.

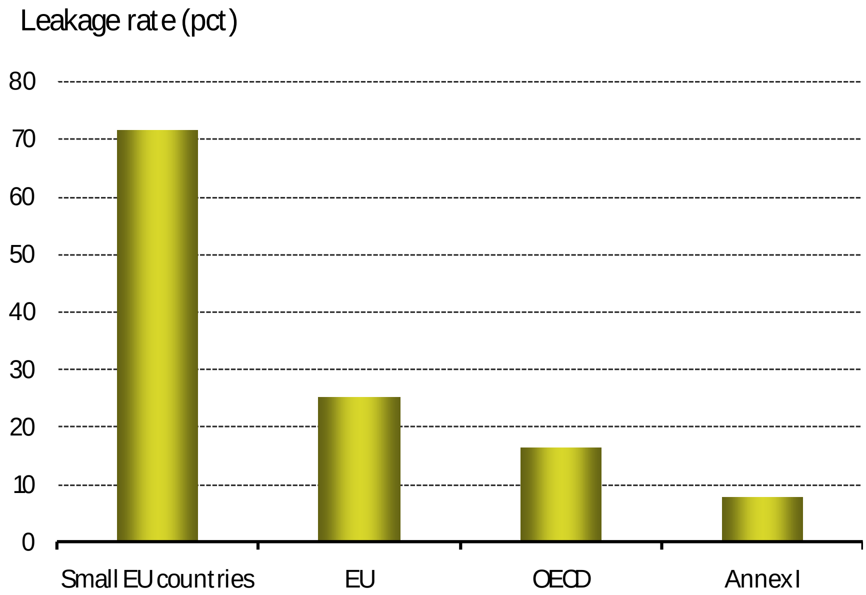
Figure: Shares of value added for key leakage industries, 2007



Source: See figure 9 in the report.

There is a large variation in estimates of carbon leakage in the literature on the issue. This partly reflects underlying fundamental differences, e.g. studies that look at carbon policies in very small regions typically find higher leakage ratios than studies looking at larger regions. But the variation in leakage estimates is also a reflection of very different methodological approaches. We conduct a review of these estimates in our study.

Figure: Leakage rates depending on region size



Source: See figure 10 in the report.

One basic conclusion we draw is that a large number of studies tend to underestimate the size of leakage, particularly seen from a long term perspective. Essentially, they tend to overlook the ramifications of the basic fact that most leakage-exposed sectors produce quite homogenous products such as steel, aluminium, paper and pulp (as in the Nordic countries) which are traded in global markets to customers all over the world with limited long term price differences. Basically, this implies that even small price differentials with regions outside the Nordics will shift most (if not all) demand abroad, and production will be dramatically reduced, especially over the long term once existing production facilities are run down. Studies that allow for such longer term effects and recognise the "commodity-characteristic", find leakage rates approaching 100 per cent and even exceeding this.

We have included in our report some illustrative model results from our own model, mainly to illuminate and explain the effects associated with carbon leakage. We suggest that leakage rates for the key Nordic industries at risk of leakage approach 100 per cent in the short run and even exceed 100 per cent in the long run. This implies that imposing a substantial carbon price in the Nordics will essentially not reduce global emissions but instead lead to production displacement.

The functioning of power markets are of particular interest in a Nordic carbon leakage discussion. Leakage exposed industries in the Nordics tend to get most of the energy as electricity from the power grid while corresponding firms in other EU countries tend to produce more of their own energy. This also implies that Nordic electricity consist of a very low-carbon energy mix (hydro, wind, atomic power) relative to their counterparts in other EU countries. Moreover, power generators in Nordic countries are highly efficient in converting coal and gas to electricity. These two factors in conjunction imply that every unit of energy intensive production moved from the Nordic area to other parts of EU or other parts of the world are likely to be followed by a net increase in carbon emissions (increased carbon intensity per unit of production globally.).

Such effects will only partly be offset by increasing the exports of redundant "clean" electricity for several reasons. Existing infrastructure cannot facilitate such a massive increase in exports. Moreover, competitors to Nordic firms in key industries such as steel, paper and pulp production are in any case placed outside the EU, so they are not the marginal beneficiaries of surplus green electricity from the Nordic area. Finally, with a fixed amount of ETS allowances and a lower demand for allowances from leakage exposed industries, the allowance price will fall. Hence, the net effect of reduced electricity demand from leakage exposed industries will be an increase in demand - and hence higher level of emission - from non-leakage exposed industries, due to the lower electricity price within EU and the shift of carbon intensive production towards non-EU countries.

Hence, we recommend that the Nordic countries nationally and in the context of EU political discussions take carbon leakage seriously. In chapter 4, we examine a number of the present options to deal with carbon leakage both in EU and in a global context, both from a theoretical and from a practical perspective.

We have also identified at least two areas where a more common Nordic perspective may be warranted:

First, a special focus on energy intensive industries using electricity. Most of the debate within the EU has focused on providing free allowances to energy intensive firms in international competition. However, it is only firms with own energy production that can benefit from allowances, not firms exposed to carbon pricing through their use of electricity from the grid. This is a decision that may be difficult to change now. However, the Nordic countries should look carefully into the State aid framework for compensating energy intensive electricity users, currently in the process of being reviewed and expanded by the Commission, to see if it provides the proper balance between the use of different types of energy, and neither over nor under compensates industries. Moreover, as the compensation to electricity consumers is to take place by national measures, and as there are a lot of similarities in terms of leakage exposed industries within the Nordic countries, the argument for ensuring consistent treatment in EU regulation in order to avoid very strong distortions between firms in the Nordic region weighs even heavier.

Second, in a wider global climate policy context the Nordic countries may also share some common interests. All countries are heavily engaged in global trade and have a tradition for and an interest in supporting open markets and trade liberalisation. Some of the measures currently on the table to deal with carbon leakage, such as import tariffs on products from regions with weak climate policies, seem in theory well targeted to deal with carbon leakage but are very difficult to implement in practice. Moreover, such measures may be difficult to reconcile with an open market mindset. We suggest taking other possible routes that have more success in disseminating climate policies at the global level such as expanding emission trading schemes to other countries or engaging in other types of bilateral agreements addressing carbon leakage.

1. Drivers and size of carbon leakage

1.1 What is carbon leakage?

In order to reduce carbon emissions, the most efficient instrument is to increase the price on carbon. A price on carbon will influence two behavioural channels: 1) consumers and industries change their behaviour to consume less carbon e.g. by buying fewer cars and/or driving fewer kilometres, and 2) consumers and industries substitute their consumption towards goods that use carbon more efficiently e.g. smaller and/or more fuel efficient cars. These effects are illustrated in the lower panel in Figure 1.

Carbon abatement policies such as increasing the price on carbon will reduce emissions *inside* the region adopting the policy. However, a part of this reduction may be offset by an increase in emissions *outside* the region. This effect is known as *carbon leakage*. Carbon leakage is a concept that depicts the degree to which carbon emission reductions in a region with carbon abatement policies are offset by increased emissions outside the region.[1] If, for example, the EU implements policies that reduce emissions by 100 units and emissions subsequently increase by 70 units outside EU, then the carbon leakage rate is 70 per cent.

Carbon leakage is spurred not just by an increased price on carbon. Most countries do not seek to reduce CO_2 emissions purely by putting a price on CO_2, as is the case with e.g. the EU ETS. Instead, climate policy is conducted by increasing renewable energy production capacity, increasing energy taxes, and adopting certain climate related standards for certain products, such as e.g. the efficiency of a car engine. Such policies all have a cost (e.g. higher electricity bills and higher product prices) which can be interpreted as the implicit cost of CO_2 reductions (or just the implicit price of carbon). What matters for carbon leakage is not the price of carbon per se (the ETS price in Europe), but the implicit cost of CO_2 reductions, which is the sum of the above elements.

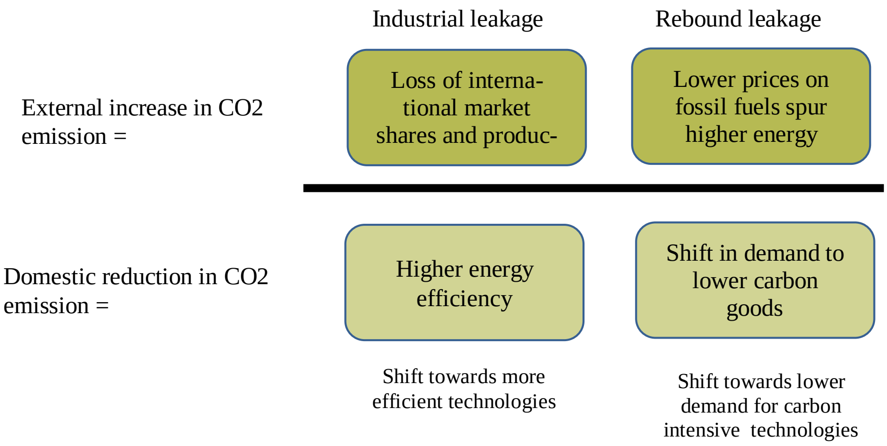
Carbon leakage may take place through two channels:

1. Domestic producers face higher production costs and will therefore lose competitiveness on the global market. Foreign competitors will

[1] See e.g. IPCC (2007).

respond by increasing production (and emissions) in order to utilise the cost differential created by the carbon tax. Moreover, domestic producers may also respond by moving production facilities abroad. This is known as *industrial (carbon) leakage*
2. By reducing energy consumption *inside* a sufficiently large region with high carbon prices this will tend to lower the global energy price. In turn this will stimulate energy demand (and emissions) *outside* the region. This is known as *rebound (carbon) leakage.* These effects are illustrated in the upper panel in Figure 1

Figure 1: Conceptual presentation of carbon leakage



Source: Copenhagen Economics inspired by IEA (2008b).

Rebound leakage is primarily of relevance when evaluating the policies of a large region. The actions of a small region, such as the Nordic region, will not have a large impact on the global energy price and the rebound channel will not be of particular importance. On the contrary, *industry leakage* is very relevant from a Nordic perspective, since the Nordic countries are small open economies with a relatively high level of carbon (and energy) taxation. Consequently, firms are facing a high degree of foreign competition, and are likely to face difficulties withstanding further reductions in their competitiveness.

There are several examples of production facilities in a region with high production cost which have been relocated to lower cost regions through competitive pressure. Classic examples are the shipbuilding industry moving from Europe to cheap-labour regions in Asia over the past five decades[2], the textile industry (one of the main drivers in the European industrial revolution) moving to South East Asia and Central

[2] Hoffmann (2004).

America[3], and mining and heavy industry moving to Eastern Europe and further East in the 1990s to take advantage of energy subsidies[4]. The last decades have taught us that businesses are becoming ever more mobile through international trade and foreign direct investments, so similar stories are likely to take place and even at a faster rate in conjunction with decreasing costs of transports.

How firms' behaviour affect carbon leakage
In response to higher cost, there are basically four options open to a firm:

1. Pass on
2. Abate
3. Innovate
4. Relocate, scale down, or close

These options are not mutually exclusive. For example, a firm may be forced to scale down even when it is also abating or innovating.

1. *Passing on tax increases to consumers* will allow firms to maintain a certain profit margin and therefore maintain production. The less able a firm is to pass on a tax increase the more likely it will succumb to international competitive pressure. The ability to pass on tax increase depends on a variety of factors including the competitive nature of the market and product differentiation (substitutability)[5]
2. *Abatement using existing technologies* will be a way of reducing the impact on production cost from a higher (implicit) price of carbon. For example, installing a Carbon Capture and Storage technology (CCS) can reduce emissions and hence reduce the impact of the tax. Yet, the technology also comes at a cost and it will not remove the burden entirely. In particular, the cost of the emission reducing technology per unit of CO_2 displaced has to be lower than the carbon price in order to be economically relevant for the firm
3. *Innovations* have a longer and more extensive time perspective. Innovations can reduce the tax burden in the future, and moreover potentially create entirely new markets where the firm can add to its profits. However, innovations that are only profitable in high-taxed regions will not be profitable in lower-tax regions, and hence cannot be exported to such regions. This makes it difficult for firms in relatively small economies, which to a larger extent sell to markets in

[3] Singleton (1997).
[4] UN (2003).
[5] See e.g. IEA (2008b).

other regions, to recover the costs of innovation and therefore has less incentive to innovate[6]

4. *Relocating, scaling down, or closing down production* is where carbon leakage becomes relevant. Scaling down production may be the objective of domestic climate policy in order to reduce emissions; however this policy is not effective if foreign firms simply take over market shares and maintain the level of global emissions. Moreover, if the current location of the production plant was chosen inter alia to minimize transportation cost (which economic theory would predict), it also implies that relocation leads to additional transportation, additional emissions, and efficiency losses

The firms' actual choices will depend on a number of drivers and brakes, which are industry-specific. We will explain these in more detail in the next section.

1.2 Drivers and brakes of carbon leakage

In this section, we look at the most important drivers and brakes that affect the size of industrial carbon leakage.[7] As mentioned above, the size of carbon leakage is a measure of how much emissions increase outside the policy-region as a response to an increase in the (implicit) price of carbon. In the EU context, policy makers are especially concerned with specific industries' *risk of carbon leakage*. An industry may be more or less at risk of carbon leakage depending on specific structural characteristics of the products produced in the industry. In the context of the EU ETS Directive, carbon leakage is primarily assessed by a product's *energy intensity* and *trade exposure*.[8] The more energy input is used per unit output, the higher the products' risk of leakage is, and moreover the higher the competitive pressure is from abroad, the higher the risk of leakage is. We however, argue that this approach is simplified. While these two variables are indisputably important for carbon leakage, trade exposure is to a large extent driven by other underlying factors, which are more interesting to evaluate, since trade exposure in itself should not be sufficient to be deemed at risk of carbon leakage. Moreover, other variables are important in order to assess the risk of carbon leakage. To be able to properly ad-

[6] See e.g. Copenhagen Economics (2010).

[7] From here on, we focus on industrial carbon leakage and not on rebound leakage, since this is what is most relevant for the Nordic countries.

[8] These two factors determine whether or not an industry can be deemed"at the risk of carbon leakage" and thereby be eligible to special treatment. From 2013, industries at risk will continue to receive 100 per cent free ETS allowances instead of the gradual reduction to 30 per cent by 2020 applicable to other industries.

dress the risks of carbon leakage of each particular industry, we argue that the following drivers and brakes should be explored:

Drivers
- 1.2.1 Energy intensity
- 1.2.2 Ability to split and outsource the production processes
- 1.2.3 Relative energy efficiency in production and fuel mix

Brakes
- 1.2.4 Transportation costs and transportability
- 1.2.5 Capital intensity
- 1.2.6 Trade barriers and exchange rate risks
- 1.2.7 Product differentiation

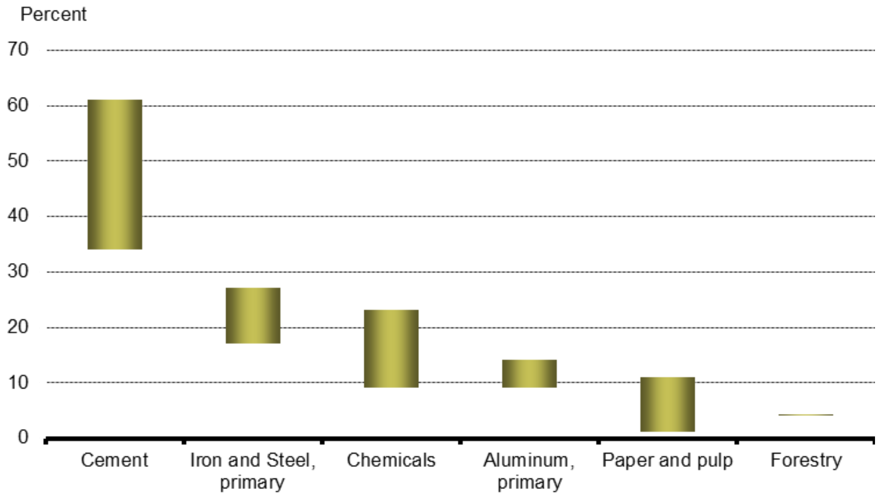
1.2.1 Energy intensity

The impact on production cost from increasing carbon costs, and the associated risk of carbon leakage, will generally (but not always) be greater in industries that use a large amount of energy. The most commonly used energy sources in the Nordic countries are electricity, fossil fuels and to a minor extent renewable energy consumed directly (not through electricity production). Increasing the implicit carbon price will affect the price of both fossil fuels and electricity (through e.g. green certificate prices, and ETS allowances prices), and therefore also the main sources of energy input. Industries that are highly energy intensive are cement, iron and steel, refined petroleum, fertilisers, chemicals, aluminium and pulp and paper.[9]

The production costs of industries such as aluminium, chemical, and iron and steel are estimated to increase by more than 10 per cent for a carbon price of €20 per ton, cf. Figure 2. The cement industry is the most vulnerable with increased production costs of up to 60 per cent.

[9] See e.g. Hourcade et al. (2007).

Figure 2: Short run impact on production costs from a carbon price of €20 per ton



Note: The studies consider a carbon price of €20 per ton. Note also that the studies only consider the direct impact on production costs and not the opportunity costs related to the relative price of renewable energy waste products cf. the discussion below. This is especially relevant for the paper and pulp industry with supply of waste materials from wood processing.

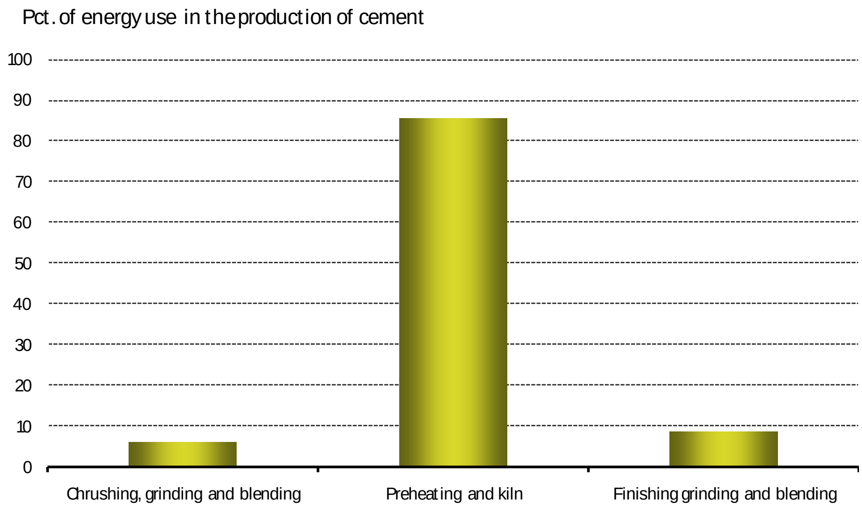
Source: Copenhagen Economics based on IEA (2005), Smale et al. (2006). McKinsey and Ecofys (2006), and Climate Strategies (2007).

Industries that use a large share of renewable energy in production will not be directly affected as much by an increase in the carbon tax, and may even benefit through a better competitive standing. Due to this, it may be relevant to also consider the *fossil fuel intensity*. However, even for industries that use a lot of renewable energy there is an opportunity cost of consuming this energy. As the price of carbon intensive energy sources increase, renewable energy becomes increasingly attractive and hence demanded more. This drives up either the direct cost of purchasing renewable energy or the opportunity cost of consuming own production of renewable energy instead of selling it on the market. Industries in the Nordic region where these arguments are relevant are related to the paper industry, where renewable energy is consumed directly due to the combustible waste products associated with processing wood.

1.2.2 Ability to split and outsource the production process

Carbon leakage may occur since the impact of an increased price of carbon on production costs can be mitigated by outsourcing the most energy intensive part of the production process to regions with lower prices on carbon. One prominent example of such splitting and outsourcing is clinkers which are used to produce cement. Producing clinkers by heating limestone in a kiln is by far the most energy intensive process of cement production, cf. Figure 3. Consequently, by relocating clinkers production to regions with low carbon prices, firms may save a substantial amount of production costs.

Figure 3: Energy use in production of cement



Source: Copenhagen Economics based on IEA (2008b).

Some industrial processes are not currently outsourced due to physical or structural limitation, while others are not outsourced since e.g. the transport costs are too high. Cement has previously been considered a product unsuitable for outsourcing, but due to a sufficiently high carbon price a substantial outsourcing of clinkers production takes place today. For example, imports of clinkers from Morocco and Egypt to Spain were substantial during the construction boom in Spain in 2003-2006.[10]

1.2.2 Relative energy efficiency in production and fuel mix

The size of carbon leakage will depend on the relative energy efficiency between firms in the region with a high carbon price and the region without. If the firms in the region with a carbon price are relatively more energy efficient than in the low-tax region, there will be an increase in total carbon emissions for each unit production that is moved from the taxed to the non-taxed region and vice-versa. This may theoretically give rise to a leakage rate above 100 per cent. A study we conducted in relation to Danish energy taxation found a carbon leakage rate of 88 per cent, inter alia

[10] Ponssard and Walker (2008)

contributed to the fact that Danish production was relatively energy efficient compared to the regions with a lower carbon price.[11]
Moreover, the fuel mix used in production in various regions will also affect the size of carbon leakage. This is especially relevant in electricity production where the fuel mix in different regions and countries vary substantially from app. 10 per cent (several Eastern European countries) to 99.9 per cent (Iceland). If production moves from a region with a high share of renewable energy to a region with a lower share, emissions will consequently increase per unit of production hence increasing carbon leakage.[12]

1.2.3 Transportation costs and transportability

Transportation costs will among others determine how competitive a geographically distant producer is. If it is very costly to bring the product to the market, there is both limited competition from abroad and a limited scope for moving production away. Products will thus be less at risk of carbon leakage when transportation costs are high. This is also equivalent to the fact that carbon leakage risks has increased in conjunction to globalisation and the structural reductions in transportation costs.

Transportation costs are closely related to product characteristics. Fresh milk is heavy and easily decomposed and therefore expensive to move. Milk powder, on the other hand, can be stored at limited costs and is much more weight-efficient to transport. A similar example holds for cement where clinkers (the input) are cheaper to transport than actual cement (the output) (see also above). Products with high storability and low weight/value ratios are therefore generally more at risk of carbon leakage as they are both relatively cheap and possible to transport.

Other factors such as health and environmental factors could also have an impact on the tradability of a product. Chlorine, for example, is a hazardous substance that makes it less suitable to transport, thus reducing the ability to substitute foreign production for domestic production and therefore reducing the risk of carbon leakage.[13]

1.2.4 Capital intensity

While the current costs of carbon taxes are relatively easy to estimate, there is much more uncertainty about long-term effects on both costs and production. Consider for example industries that are relatively capital-intensive. Since capital-intensive firms normally have undertaken

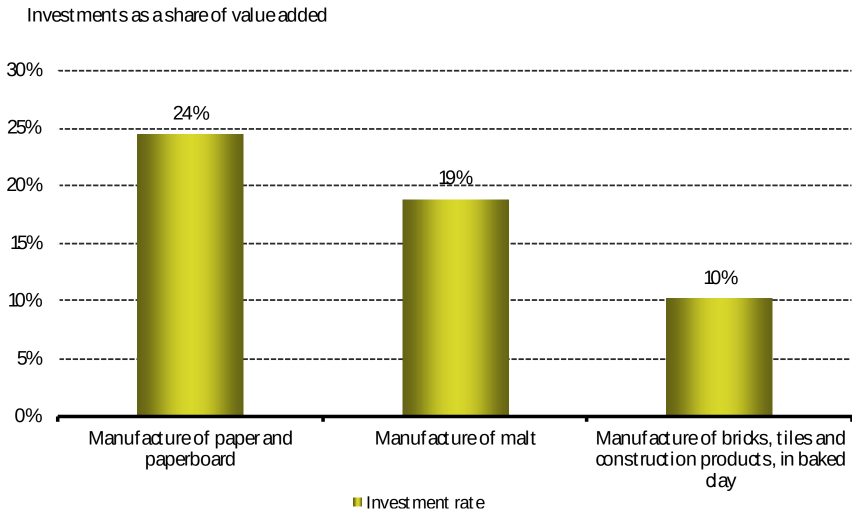
---

[11] Copenhagen Economics (2011).
[12] See e.g. TNO (2009).
[13] Congressional Research Service (2008).

significant investments up front, such firms may respond to competitive pressure by lowering prices but remaining in business until new investments are due. When the capital stock is sufficiently depreciated, firms may either find it unprofitable to undertake new investments and close production, or move production to regions with lower carbon prices.[14] In such a case, carbon leakage will be much higher in the long run than in the short run, and carbon leakage based on current observations and modelling may be underestimated.

In order to assess capital intensity, we consider industries' investment rates.[15] The capital intensity varies across industries, with e.g. manufacturing of paper and paperboard investing with a rate of 24 per cent, cf. Figure 4. This suggests that carbon leakage in industries such as the paper and paperboard industry tend to materialise in the longer run since firms will not close down production immediately due to their large capital investments. This will be discussed further in Chapter 2.

Figure 4: Capital intensity of different industries



Note: Calculated as an average of the Nordic countries where data was available.

Source: Copenhagen Economics based on Eurostat - Annual detailed enterprise statistics.

[14] Under the condition that production does not lead to economic losses. In this case the proper response is to close down production immediately.

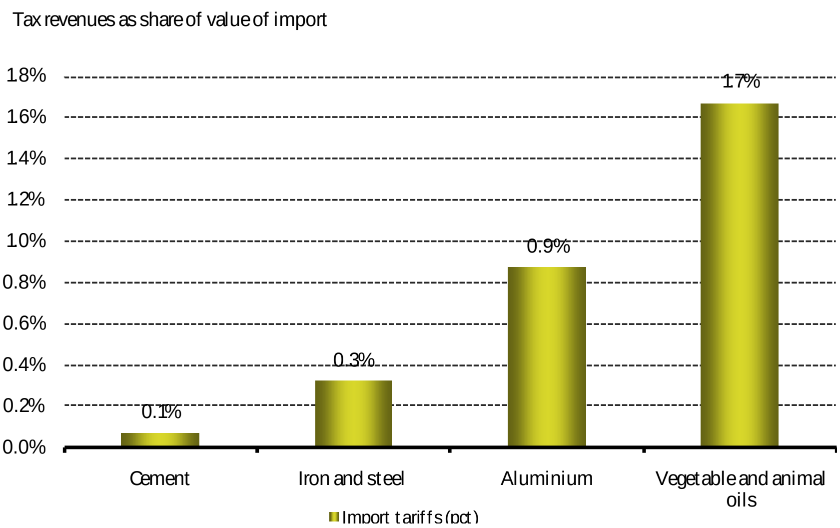
[15] The investment rate as is a fairly good approximation for capital intensity, since a large capital stock requires a relatively high investment rate to maintain the capital stock level. This measure does not however, capture that there may be different capital depreciation rates between industries, and is therefore not a perfect approximation.

1.2.5 *Trade barriers and exchange rate risks*

A reverse driver, i.e. a brake, of carbon leakage is the existence of trade barriers. If a region has set up trade barriers e.g. in the form of import tariffs or non-tariff barriers, foreign produced goods will be more expensive and hence less attractive in the domestic market. By increasing the price of goods from low carbon price regions, the price differential between regions with ambitious and less ambitious climate policies respectively is reduced. Consequently, this reduces the risk of carbon leakage.

EU import tariffs vary largely across products. While tariffs on vegetable and animal oils generate 1.7 per cent tax revenue per value of import, tariffs on cement only generate 0.1 per cent revenue per value of import, cf. Figure 5. This indicates that products such as vegetable oils are less at risk of carbon leakage than they would be if import tariffs were lower.

Figure 5: Import tariffs on different products



Note: Import tariffs are calculated at an EU aggregate level. Specific Norwegian import tariffs are not included here.

Source: Copenhagen Economics based on WITS database.

This suggests that intra-EU leakage rates, *for a given energy-price differential*, may be higher than e.g. between EU and third countries, since there are no import tariffs between EU Member States. In the absence of any trade barriers, even small price differentials e.g. between the Nordic countries and the rest of EU may give rise to intra-EU leakage.

While probably less important, the existence of exchange rate risks may also be a (reverse) driver of carbon leakage. The higher the exchange rate risk is perceived; the more risk is associated with relocating production abroad. This will lower the incentive to move production abroad and hence reduce the risk of carbon leakage.

1.2.6 Product differentiation

The degree of international product differentiation is a key driver in determining the degree of leakage. This is so, since product differentiation affects the competitive environment and hence the ability for firms to pass on production cost increases to consumers. Consider first one product type produced in two different regions that has different value to consumers (e.g. home bias towards agricultural products). Such a differentiated product allows domestic producers to maintain a higher price since domestic consumers prefer domestically produced goods. Consider secondly a product, which is essentially the same across countries (such as refined oil, cement, aluminium etc.). A small price increase in such a homogenous good can spur a massive substitution towards the cheaper good. Such a homogenous good is known as a commodity, and most products that are normally recognised as being at the risk of carbon leakage are commodities.

Product differentiation is a key requisite for firms to be able to pass on price increases to consumers, and thus its ability to recover the cost induced by a CO_2 price without significantly undermining international competitiveness. In case of a homogenous commodity, domestic producers cannot increase the price in response to a tax increase without losing substantial market shares to foreign competitors. Consequently, the more homogenous a good is perceived to be, the larger the risk of carbon leakage. In fact, it has been shown that when the modelling framework is able to account for homogenous goods instead of differentiated goods, carbon leakage rates increase dramatically and may be well above 100 per cent.[16]

1.3 Leakage rates may change over time

An analysis of carbon leakage should take into account that leakage drivers (and brakes) may change over time. Consider, for example, the two variables: energy intensity and trade intensity. Both these factors have a tendency to change over time, and this change may, to a large extent, be driven by increases in the carbon price. While this point is acknowledged by the European Commission,[17] this is important when interpreting economic modelling of carbon leakage rates. Most models are linear in the carbon price, and do therefore not consider so-called tipping points that may occur, if leakage rates begin to increase when carbon prices reach a certain threshold, which is very likely from a theoretical point of view.

---

[16] See e.g. Babiker (2005) that uses homogenous Hekscher-Ohlin goods instead of differentiated goods modeled with Armington elasticities.

[17] The list of sectors and subsectors determined by the European Commission to be at risk of carbon leakage is updated app. every fourth year, and sectors and subsectors may be added each year through a Comitology decision.

Consider first *energy intensity*. While the emissions released from the chemical reaction required to generate clinkers from heating lime stone cannot be changed, the energy usage in the process may be, e.g. by investing in more innovative heating methods such as e.g. better insulated ovens. The higher the carbon price becomes, the higher the incentive to invest in innovation of energy efficient technologies becomes. The energy intensity in production is consequently expected to decrease.[18]

Consider now *trade exposure*. Trade exposure is a good measure of a product's tradability and whether or not it would be possible to move production abroad and serve the domestic demand from abroad. Current and/or historic trade exposure is however very much dependent on e.g. the relative prices at a given point in time, including import tariffs etc. The characteristics of most goods entail that they will be profitable to trade if the price differential becomes large enough. As long as the differential has not reached this "tipping-point", no trade will take place. But once the tipping-point has been reached, an industry may be massively exposed to international trade.

Two prime examples of industries, where the risk of carbon leakage has or is expected to increase substantially over time, are *cement production* and *electricity production*. Historically, *cement production* would not be considered to be exposed to a large amount of trade, especially due to its high weight-to-value ratio. However, as a result of relatively low transport costs and high energy prices, it has been possible to split up the cement production chain, and move the energy-intensive element in production (clinkers) to low-carbon price regions. In *electricity production*, tradability is determined by the available infrastructure. The lack of interconnectors between EU and third-countries has made carbon leakage risks outside EU largely unfounded. Interconnectors are however being established to e.g. Russia, Ukraine, and North Africa which will make the electricity industry heavily exposed to extra-EU trade, and substantially increase the risk of carbon leakage as a result of the large carbon price differential with these regions.

1.4 Size of leakage estimates

Much empirical work has attempted to measure leakage rates associated with different policies, e.g. compliance with the Kyoto targets or compliance with the ETS reduction targets. The higher the rate of leakage, the less effective and potentially the more distortive is the policy: It can re-

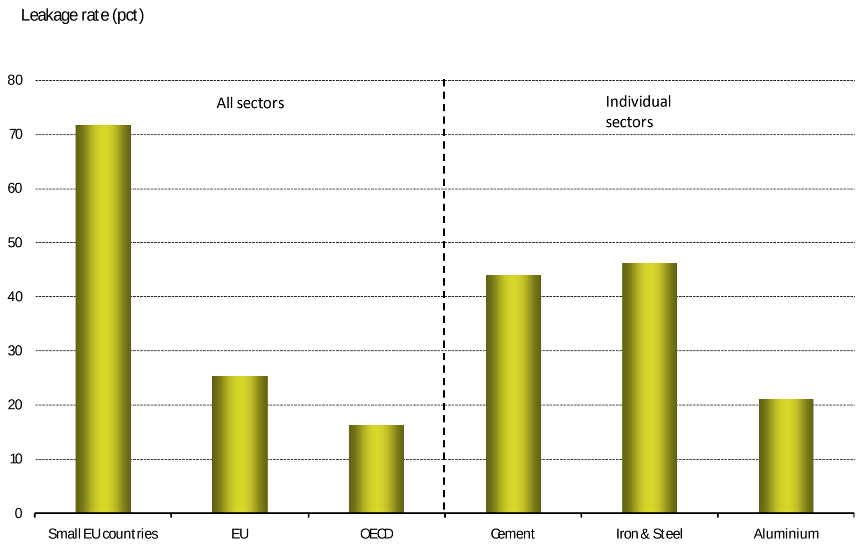
---

[18] As we stress above however, unilateral carbon price increases in geographically small regions will most likely not have a substantial effect on innovation, since these innovations may not be cost effective enough to be exported to low-tax regions.

sult in moving production to other countries that are *currently*[19] unable to compete on equal terms with domestic producers, leading to a less efficient use of world resources.

Typical macro estimates with conservative assumptions lie in the range of 10–30 per cent for large geographical areas such as the OECD or EU, while smaller geographical areas – such as Sweden and Denmark – tend to have significantly higher leakage rates of app. 60–90 per cent, cf. the left panel of Figure 6. Micro estimates tend to be higher than macro estimates and are often in the range of 40–50 per cent for energy intensive industries such as cement and iron and steel, cf. the right panel. Figure 6.

Figure 6: Leakage rates depending on region and sector



Note: The results are averaged over different model assumptions so the leakage rates are not directly comparable across size and sectors.

Source: Copenhagen Economics based on CPB (2011a), CPB (2011b), Antimiani et al. (2011), Copenhagen Economics (2011), OECD (2003), OECD (2009), Bohlin (2010), Babiker (2005), Burniaux & Martins (2000), Burniaux & Truong (2002), Böhringer et al. (2010), Demailly & Quirion (2008b), Gerlagh & Kuik (2007), Kuik & Gerlagh (2003).

A thorough review of different carbon leakage estimates will be conducted in Chapter 3.

[19] The fact that local producers are currently able to deliver goods to the domestic and global markets strongly suggests that they are at least as efficient as their foreign competitors. In some cases, part of the efficiency advantage comes from an optimal location (minimisation of transport costs and access to resources), while other cases are due to e.g. superior technologies.

2. Identification of Nordic industries at risk of carbon leakage

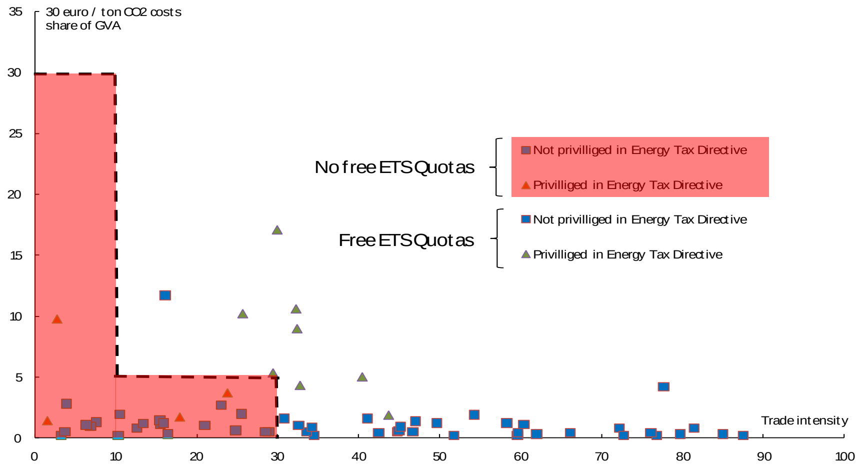
An important issue for policy makers is to determine which industries that are at the risk of carbon leakage. The approach used by the European Commission is to consider two factors: energy intensity and trade intensity. The industries at risk are the ones that fulfil one of the following three criteria:[20]

- The additional costs induced by carbon tax is at least 30 per cent of Gross Value Added (energy intensity)
- The Non-EU Trade intensity is above 30 per cent
- The additional cost induced by carbon tax is at least 5 per cent of Gross Value Added *and* the Non-EU Trade intensity is above 10 per cent

This approach is depicted in Figure 7. The industries that lie within the red shaded area are *not* deemed at risk according to the EU approach.

[20] Certain qualitative criteria are also applied to industries that do not fulfill the quantitative criteria.

Figure 7: Energy- and trade intensity



Note: Industries measured on a NACE 3-digit level. Energy intensity is here measured as amount of CO_2 emissions multiplied with an estimated ETS price of €30 pr. ton CO_2

Source: Copenhagen Economics based on data from Statistics Denmark and European Commission (2009). The ETS quota allocation is based on Directive 2009/29/EC amending 2003/87/EC. The Energy Tax Directive refers to Directive 2003/96/EC.

While this approach is a good starting point, we argue that a detailed analysis must include more variables than energy and trade intensity. The risk of carbon leakage should in fact be determined according to all the drivers listed in Chapter 1. Our basic argument is that trade intensity of a product is a consequence of the underlying drivers of carbon leakage, not a driver in itself.

In this chapter we will qualify the drivers from Chapter 1 and identify the industries in the Nordic countries that are deemed to be at risk of carbon leakage based on the information revealed by these drivers. We begin this chapter, however, by describing why the level of aggregation is important in any carbon leakage analysis.

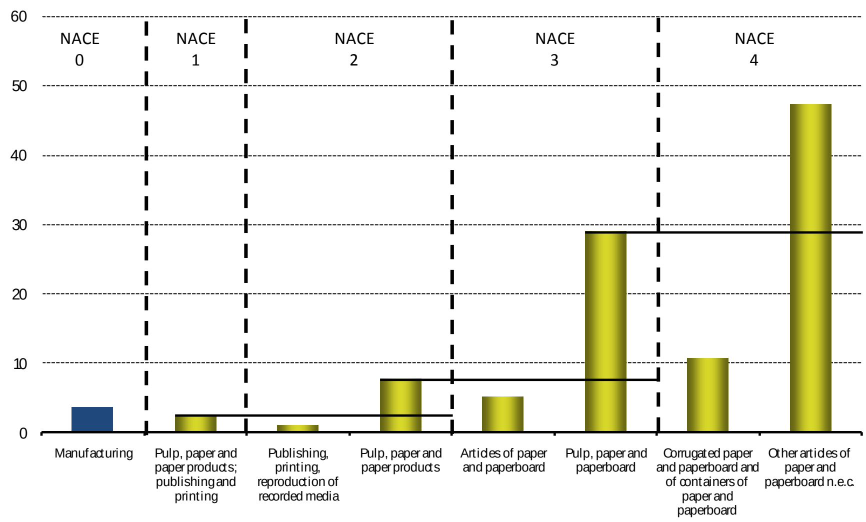
2.1 Importance of disaggregating the industrial structure

Energy intensity and other leakage-related factors can vary substantially between different processes in a production chain. This makes it important to consider such data on a detailed industry level. By using a level of aggregation that is "too high", one runs the risk of levelling out differences in an industry, leading to a loss of important information.

The paper industry is a good example of how certain energy-intensive processes would be ignored if one were to choose an inadequately detailed aggregation level, cf. Figure 8. The first two columns depict the energy intensity measured on a very aggregate industry level

(NACE 0: Manufacturing, and NACE 1: pulp, paper, and paper products). By moving to a higher level of disaggregation (moving right in the diagram), the energy intensity of different processes in the production chain becomes evident. In fact, the processes "pulp, paper, and paperboard", and the even more disaggregated "other articles of paper and paperboard" have significantly higher levels of energy intensity, which would be ignored by using a higher aggregation level.

Figure 8: Energy intensity in industrial subsectors – Paper industry



Source: Copenhagen Economics (2011), based on data from Eurostat, structural business indicators.

Based on these considerations, we will use data on a NACE-4 level to as large extent as possible. For energy intensity, this is available for almost all industries in all Nordic countries, except Iceland.

2.2 Our approach to identify leakage industries

In order to evaluate which Nordic industries that are at the risk of carbon leakage, we will take reference in the drivers and brakes identified in Chapter 1. Identifying industries at the risk of leakage is interesting in itself. Such industries are, at EU level, eligible both for free ETS allowances, various energy tax exemptions in accordance with the Energy Tax Directive and special treatment with respect to EU State aid guidelines. In order to apply different policy instruments effectively and efficiently, determining the industries at risk of leakage is crucial. When we have established the industries at risk of carbon leakage, we will evaluate the size of the leakage rate based on those industries through a modelling exercise in Chapter 3.

The primary driver of carbon leakage is the share of CO_2 used in production. Due to lack of sufficiently detailed data on CO_2 emissions, a good approximation is energy consumption.[21] We therefore begin by creating a list of industries (on a NACE-4 level) for each Nordic country based on industries that have an energy intensity higher than 10 per cent, measured by cost of energy in production as a share of value added. We then condense this gross list into a net list by using information from the remaining 4 drivers. The drivers and brakes, which we consider, including the data we use, are listed in Table 1.

Table 1: Drivers, brakes, and data sources

Drivers and brakes for leakage	Part of ranking	Data source
Drivers		
Share of energy costs in production	Gross list	Purchase of energy pr. industry. Data is available from Eurostat on NACE 4-digit for most industries but only on NACE-3 digit for some. Note: Data is not available for Iceland
Relative efficiency in production	Gross list	Value added at factor costs on a NACE-3 and NACE 4-digit (and energy use above) based on Eurostat detailed industry statistics. Note: Data is not available for Iceland
Possibility of splitting the individual processes	Net list	Qualitative assessment based on available knowledge in the literature
Brakes		
Transportability	Net list	Assessed by the weight-to-value ratio. Weight-to-value is measured from trade statistics on traded quantities and values, on a detailed product level. Available from the WITS database
Capital intensity	Long term net list	Assessed by the investment rate as a share of value added
Trade barriers	Net list	Tariffs from the WITS database
International product differentiation	Net list	Assessed by trade intensity. Data available from Eurostat on NACE-4 level

Source: Copenhagen Economics.

Data on several drivers, inter alia energy intensity, has not been available for Iceland. Iceland is a unique case in the sense that the share of electricity intensive industries (especially aluminium) is very large, and moreover that all electricity in Iceland is produced from renewable sources with no carbon emissions. Based on this, we expect Icelandic industries in general (electricity intensive industries in particular) to be largely unaffected by carbon prices. On the other hand, such industries are still responsive to other energy prices such as e.g. a tax induced increase in the price of electricity. This is further expanded in Box 1.

[21] This will be discussed further below.

Box 1. Expectations regarding carbon leakage in Iceland

Iceland has a relatively large bulk of electricity intensive industries out of total production.[1] This is largely due to aluminium production. This can be attributed to relatively low electricity prices in Iceland due to the vast amount of renewable energy used in electricity production, which on the margin generally is cheaper than electricity produced by fossil fuels.

All electricity production in Iceland (99.9%) stems from renewable energy sources. [1] This implies that electricity intensive industries, such as the aluminium industry, is largely unaffected by carbon prices. On the contrary, the relative cost of production of Icelandic aluminium decreases when carbon prices elsewhere increase. This implies that Icelandic aluminium industry is not at risk of carbon leakage, and may in fact even benefit from higher global carbon prices.

Renewable energy sources also constitute a large share (app. 80% in 2008) of total gross energy consumption.[1] Hence, Icelandic industry as a whole is also expected to be much less affected by carbon prices than most EU counterparts, and thus less at risk of carbon leakage.

While Icelandic industries may be less responsive to carbon prices, the industries are not immune to non-carbon energy prices. In fact, since a large bulk of total production comes from electricity intensive industries, higher prices on electricity, for example driven by a (non-carbon) tax, will reduce competitiveness of Icelandic industries. This will especially be the case for energy intensive firms, which in turn might reduce production. A shift in production out of Iceland would entail a large increase in emissions per unit of production due to the very low amount of carbon input in Iceland energy use.

Source: Copenhagen Economics based on University of Iceland (2009) and energy consumption data from Statistics Iceland.

2.3 Identifying industries in the Nordic countries at risk of carbon leakage

2.3.1 Producing the gross list

The gross list is a measure of industries in the different Nordic countries which will endure the largest increases in production cost from an increase in the energy price, e.g. through national energy taxes, increases in the price of ETS quotas or through cost of financing renewable energy investments (such as green certificate prices). We have included industries where the energy intensity[22] is above 10 per cent. This is to sort out industries that will not be affected much by increasing energy prices and consequently are less at risk of carbon leakage. If the energy intensity of an industry exceeds 10 per cent in a single Nordic country, it is added to the gross list. This is done without considering the granting of free allowances in the EU ETS, since the objective of this exercise is to evaluate industries at risk of carbon leakage prior to EU "anti-leakage" measures.

When considering energy intensity, we look at the cost of energy input. The correct measure would in fact be the cost of fossil fuel input, since direct renewable energy inputs are not directly affected by a carbon tax. However, the real issue is the extent to which carbon taxes affect the energy costs facing enterprises; and that depends on a number of different issues. In the Nordic power generation system, the marginal producers in the electricity system are gas and coal plants. Hence, the price of electricity is determined by the price of fossil fuel inputs, which implies that the actual input mix is less important for electricity users, and that energy intensity is a reliable approximation, at least in the long run. This is discussed more thoroughly in Chapter 3.

The gross list contains a total of 40 industries, cf. Table 2. These industries may be energy intensive in several Nordic countries or in a single Nordic country. While industries such as manufacture of paper and paperboard have high energy costs in all Nordic countries, some industries such as manufacture of distilled potable alcoholic beverages are only energy intensive in one country (Finland).

Table 2: The gross list – energy intensive industries. Purchase of energy products as a share of value added

Nace	Industry	Denmark	Finland	Sweden	Norway
152	Processing and preserving of fish and fish products	14%			10%
1531	Processing and preserving of potatoes			24%	13%
154	Manufacture of vegetable and animal oils and fats	18%			
155	Manufacture of dairy products		12%		
1562	Manufacture of starches and starch products	13%		72%	
1571	Manufacture of prepared feeds for farm animals		16%		13%
1583	Manufacture of sugar		34%		
1591	Manufacture of distilled potable alcoholic beverages		11%		
1597	Manufacture of malt	15%	24%		
172	Textile weaving		20%		
173	Finishing of textiles	13%	14%	13%	
1753	Manufacture of non-wovens etc., except apparel		30%		
191	Tanning and dressing of leather				10%
201	Sawmilling and planing of wood		14%	14%	
202	Man.of veneer sheets, plywood, laminboard etc		19%	20%	17%
2111	Manufacture of pulp		18%	33%	32%
2112	Manufacture of paper and paperboard	34%	49%	41%	52%
2122	Manufacture of household and sanitary goods etc.		20%		22%
232	Manufacture of refined petroleum products			18%	
2411	Manufacture of industrial gases	12%	33%		

[22] Measured as cost of energy input in production as a share of value added, which is not entirely the same measure used by the Commission.

Nace	Industry	Denmark	Finland	Sweden	Norway
2412	Manufacture of dyes and pigments		23%		56%
2413	Manufacture of other inorganic basic chemicals		33%	33%	24%
2414	Manufacture of other organic basic chemicals		12%	18%	23%
2415	Manufacture of fertilizers and nitrogen compounds		18%		66%
2416	Manufacture of plastics in primary forms	10%	19%	18%	19%
2441	Manufacture of basic pharmaceutical products		26%		
261	Manufacture of glass and glass products	13%	11%	17%	10%
2626	Manufacture of refractory ceramic products				19%
264	Manufacture of bricks, tiles etc.	24%	40%	21%	53%
265	Manufacture of cement, lime and plaster		35%	46%	25%
2662	Manufacture of plaster products for construction purposes		30%		30%
2664	Manufacture of mortars				10%
2682	Manufacture of other non-metallic mineral products		16%	19%	
271	Manufacture of basic iron and steel and of ferro-alloys		14%	24%	35%
272	Manufacture of tubes			13%	
2742	Aluminium production		11%	28%	41%
2744	Copper production		21%	20%	
2745	Other non-ferrous metal production				26%
275	Casting of metals	16%	11%	12%	9%
2951	Manufacture of machinery for metallurgy		10%		

Source: Copenhagen Economics based on Eurostat data.

Not all industries that have high energy cost are necessarily at risk of carbon leakage. In addition, industries with medium energy intensity can be more at risk of leakage than industries with high energy intensity when other characteristics are taken into account. To account for this, we apply the drivers identified in Chapter 1 to the industries listed in Table 2 in order to identify the sectors that are the most at risk of carbon leakage.

2.3.2 Quantifying the leakage drivers

In order to condense the gross list, we consider three drivers in addition to energy intensity: transportability (measured by weight/value ratio), trade barriers (measured by import tariffs), and international product differentiation (measured by trade intensity). Moreover, we also consider the size of the industries, in order to filter out industries that have a negligible economic importance in the Nordic countries. In addition to this, we have applied knowledge on whether industries can split up and outsource part of the production process.[23] Finally, we also include information on capital intensity in order to evaluate the time horizon of leakage in these industries.

For each industry in the gross list, we have assigned a quantitative score for every driver. In this way, we are able to isolate what drives leakage in each particular industry, which can provide information on which

[23] It has not been possible within the scope of this study to obtain sufficient sector specific information to make a high-quality evaluation. Instead, we have qualitatively evaluated the industries where information is readily available, such as e.g. the classic example of outsourcing the production of clinkers from cement production.

policy instruments will be most effective in various industries. The scores (where 1 is not driving leakage risk and 5 is driving leakage to a very large extent) are summarised for all industries in the gross list in Table 3. The methodology used to assign the scores is described in Box 2.

Table 3: Quantifying the drivers and brakes

NACE	Industry	Energy intensity	Product differentiation	Transportability	Trade barriers	Economic importance
152	Processing and preserving of fish and fish products	1	5	4	3	5
1531	Processing and preserving of potatoes	3	2	1	3	2
154	Manufacture of vegetable and animal oils and fats	2	3	3	4	3
155	Manufacture of dairy products	1	1	1	5	5
1562	Manufacture of starches and starch products	5	1	2	3	1
1571	Manufacture of prepared feeds for farm animals	2	1	3	3	4
1583	Manufacture of sugar	4	1	2	4	2
1591	Manufacture of distilled potable alcoholic beverages	1	2	4	5	2
1597	Manufacture of malt	3	2	2	5	1
172	Textile weaving	3	5	5	3	2
173	Finishing of textiles	1	5	5	3	2
1753	Manufacture of non-wovens and articles made from non-wovens, except apparel	4	3	5	3	1
191	Tanning and dressing of leather	1	5	5	4	1
201	Sawmilling and planing of wood; impregnation of wood	2	3	3	4	5
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	3	3	3	4	4
2111	Manufacture of pulp	4	3	2	5	5
2112	Manufacture of paper and paperboard	5	3	2	5	5
2122	Manufacture of household and sanitary goods and of toilet requisites	3	2	5	5	3
232	Manufacture of refined petroleum products	2	2	2	4	5
2411	Manufacture of industrial gases	4	4	2	3	3
2412	Manufacture of dyes and pigments	5	4	5	3	2
2413	Manufacture of other inorganic basic chemicals	4	4	3	3	4
2414	Manufacture of other organic basic chemicals	3	4	3	3	4
2415	Manufacture of fertilizers and nitrogen compounds	5	4	2	4	2
2416	Manufacture of plastics in primary forms	3	4	4	4	4
2441	Manufacture of basic pharmaceutical products	4	5	5	4	3
261	Manufacture of glass and glass products	2	2	1	5	4

NACE	Industry	Energy intensity	Product differentiation	Transportability	Trade barriers	Economic importance
2626	Manufacture of refractory ceramic products	2	4	5	4	1
264	Manufacture of bricks, tiles and construction products, in baked clay	5	1	3	3	1
265	Manufacture of cement, lime and plaster	5	1	1	4	3
2662	Manufacture of plaster products for construction purposes	4	1	1	4	1
2664	Manufacture of mortars	1	1	1	5	2
2682	Manufacture of other non-metallic mineral products n.e.c.	2	2	1	5	3
271	Manufacture of basic iron and steel and of ferro-alloys	5	3	4	5	5
272	Manufacture of tubes	1	4	4	5	4
2742	Aluminium production	5	5	4	4	5
2744	Copper production	3	5	3	4	3
2745	Other non-ferrous metal production	4	5	4	4	3
275	Casting of metals	2	5	4	5	4
2951	Manufacture of machinery for metallurgy	1	5	1	5	1

Source: Copenhagen Economics based on data from Eurostat and WITS.

Note that the drivers are quantified for the Nordic countries as a whole. Transportability and product differentiation are product specific measures and is not expected to vary across countries. Trade barriers are EU import tariffs and are therefore the same for all Nordic countries.[24] Moreover, it is unlikely that investment rates within the Nordic industries should consistently vary across the countries and the data do in fact confirms this picture. The only criteria that vary significantly between the Nordic countries are the relative economic importance and the energy intensity. While energy intensity already have been evaluated country-specifically, we have made a sector specific assessment in order to ensure that the economic importance criterion does not exclude sectors that may be important in a few (or one) Nordic countries but only has an insignificant importance for the Nordic region as a whole.

[24] There are no significant Norwegian import tariffs on the products in the industries that are included in the gross list.

Box 2. Methodology used to assign scores to each driver

The scores on almost all drivers are assigned based on a percentile approach. This means that generally the 20% highest observations are assigned the score "5", while the 20% lowest are assigned the score "1". In order to ensure that observations with similar values get the same score, we manually re-assign some scores. This has been the case for some industries being close to the "cut-off point" between percentiles. Moreover, qualitative assessments have also been necessary in order to capture specific industry characteristics, which are explained below. Finally, scores on the "trade barrier-driver" has been assigned through a slightly different approach, which is further elaborated below.

Product differentiation

In order to quantify product differentiation, we use data on trade intensity. If a product is homogenous across countries (and thus resembles a commodity) it will most likely be traded across borders. Hence a low degree of differentiation, and thus high risk of leakage, will be associated with a high trade intensity. Some qualitative evaluation has been necessary though. Consider e.g. cement industry, which is a fairly homogenous good (within specific types of cement). Since cement is heavy, it is quite expensive to transport and thus has low trade intensity, and hence would not receive an accurate score. Quantifying this driver has thus been coupled with a qualitative evaluation of the other relevant drivers for each industry.

Transportability

In order to quantify transportability, we use data on a product's weight-to-value ratio. The higher the weight-to-value ratio is, the higher the transport costs will be, and consequently the lower the products' transportability and the risk of leakage will be. We have also made specific qualitative assessment of the industries in order to assess if a product is in fact transportable based on product characteristics. While dairy products may be relatively cheap to transport, their durability is relatively low thus making them less transportable. The score on such products has manually been adjusted in order to capture this.

Trade barriers

In order to quantify trade barriers we use data on EU and Norwegian import tariffs. Import tariffs on products from the industries on our gross list are relatively small (most are zero). Since trade barriers are a break to carbon leakage, a high tariff will be associated with a low score. Since most tariffs are neglible we have assigned relatively large scores to this driver. This is also done to reflect that while import tariffs constitute a trade barrier to non-EU products, it does not prevent leakage within EU countries, includin g the Nordic countries. The exception is again Norway, which levies national import tariffs; however Norwegian tariffs on the industries we have identified in the gross list are of relatively minor size and thus importance.

Economic importance in the Nordic countries

In order to quantify the score on economic importance, we use data on each industry's share of value added out of total Nordic value added. This is not a driver of carbon leakage, but it is included in order to filter out industries that are largely negligible in the Nordic economy. The industries filtered out according to this criteria (the ones that has a score of 1) accounts for a share of Nordic value added between 0.00 pct. – 0.02 pct., and not above 0.02 pct. of value added in any Nordic country.

Source: Copenhagen Economics.

2.3.3 Producing the net list

The net list is constructed by applying the quantitative scores to the industries in the gross list in order to filter out the industries that had the lowest scores and thus were at the lowest risk of carbon leakage. The methodology used to filter out these industries is described in Box 3.

Box 3. Methodology used to select the net list

To determine the industries at most risk of leakage, we apply two selection criteria: a quantitative and a qualitative.

Quantitative evaluation

The quantitative criterion builds on the quantified drivers described in Table 3. The criterion is designed to filter out industries that, according to a single driver, are not at risk of leakage. That is, if an industry is characterised by for example a high weight-to-value ratio it will not be deemed at risk of leakage, even though other drivers may indicate that this should be the case. If one driver is given the score "1", the industry will therefore as a general rule *not* be included to the net list. The net list is therefore derived from industries that score higher than "1" on all criteria. For industries that have a sufficiently high capital intensity however, these are not included in the short run net list, since it takes time to depreciate existing capital stock. Industries with a capital intensity score of 1 or 2 will not be included in the short run list, but may be included in the long run list.

While the quantitative method is a good starting point, there may be nuances of complex industries that it does not capture. Hence, we also conduct a qualitative evaluation.

Qualitative evaluation

In order to make sure that the quantitative criterion does not include industries that are not at risk of leakage, and more importantly filter out industries that are in fact at the risk of leakage, we make a qualitative assessment of all the industries on the gross list. This evaluation captures situations where the quantitative evaluation have not taken due ac-count of specific industry features. Our qualitative evaluation e.g. considers if some proc-esses can potentially be split and outsourced. In these cases, an industry may in fact be at the risk of leakage even though it e.g. has a high weight-to- value ratio. Moreover, we have given special attention to industries which are excluded from the net list based on one quantitative score alone. Such industries may be included in the net list nevertheless if all other criteria weigh sufficiently high.

Source: Copenhagen Economics.

By applying this methodology, we are able to identify the industries, which are at the highest risk of carbon leakage. Among these industries are paper and pulp, cement, aluminium and also fertilizers and nitrogen compounds, basic pharmaceuticals, and basic chemicals, cf. Table 4.

Table 4: The net list – industries at risk of carbon leakage

NACE	Industry
1520	Processing and preserving of fish and fish products
1562	Manufacture of starches and starch products
1583	Manufacture of sugar
172	Textile weaving
2020	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards
2111	Manufacture of pulp
2414	Manufacture of other organic basic chemicals
2415	Manufacture of fertilizers and nitrogen compounds
2416	Manufacture of plastics in primary forms
2441	Manufacture of basic pharmaceutical products
2626	Manufacture of refractory ceramic products
265	Manufacture of cement, lime and plaster
2710	Manufacture of basic iron and steel and of ferro-alloys
2742	Aluminium production
2744	Copper production
2745	Other non-ferrous metal production
275	Casting of metals

Source: Copenhagen Economics.

Almost all of these industries were deemed by the European Commission to be at significant risk of carbon leakage based on the Commission's quantitative criteria (energy intensity and trade intensity). Three industries (manufacture of veneer sheets, plywood etc, manufacture of plastics in primary form, and manufacture of bricks, tiles etc.) made the Commission's list after a qualitative assessment.

2.3.3 *Leakage risk in the longer run*

The choices available to firms as a response to carbon pricing can vary substantially over time. Over the short to medium term, firms respond by decreasing carbon emissions for example by producing less output, choosing different raw materials and energy inputs, and/or by utilising available technological alternatives.[25] Over the longer term, however, firms have greater ability to seek more radical transformations of existing technologies. Moreover, and more importantly from a leakage perspective, firms can close down large scale capital intensive production facilities, and/or relocate these to lower carbon price-regions. This implies that while certain industries can seem heavily committed in a certain geographical market due to capital-intensive production facilities etc., and thus not at risk of leakage in the short run, the risk of leakage in the long run may nevertheless be high.

We take the time dimension into account by looking at how capital intensive an industry is. The higher the capital stock, the more investments will be foregone by abandoning a plant and moving to a different location. A good approximation to capital intensity is an industry's investment rate. However, this is only an approximation. If the capital stock e.g. is very durable and thus has a low depreciation rate, the capital stock may be high even though the investment rate is low. We expect this to be the case for e.g. aluminium that has a rather high capital stock but relatively low investment rate.

The industries in the gross list with the highest investment rates (manufacture of industrial gases) invest annually app. 36 per cent of value added, cf. Table 5. Note that Table 4 only depicts the 12 industries of the gross list that have investment rates above 15 per cent.[26]

Table 5: Industries with high capital intensity

Industry	Investment rate
Manufacture of industrial gases	36%
Manufacture of paper and paperboard	28%
Manufacture of malt	27%
Processing and preserving of potatoes	26%
Manufacture of household and sanitary goods and of toilet requisites	25%
Manufacture of refined petroleum products	21%
Manufacture of prepared feeds for farm animals	20%
Manufacture of dairy products	19%
Sawmilling and planing of wood; impregnation of wood	18%
Manufacture of non-wovens and articles made from non-wovens, except apparel	17%
Processing and preserving of fish and fish products	16%

Note: Only industries from the gross list with an investment rate over 15% are included

Source: Copenhagen Economics based on Eurostat.

[25] See e.g. IEA (2008b).
[26] The investment rate has been considered for all industries in the list.

These industries are not expected to reduce production through carbon leakage in the short run due to their relatively high capital intensity. However, such industries may reduce production in the longer run when the capital stock has been sufficiently depreciated and new investments are to be made.

Based on information on capital intensity, Table 6 depicts the industries that may not be at risk of carbon leakage in the short run, since they have large existing capital investments. However, these industries are likely to be at risk in the longer run, when the investments are sufficiently depreciated. These industries are chosen technically by satisfying the following two criteria:

1. Not included in the net list in Table 4 due to a high capital intensity
2. At risk of carbon leakage based on all other drivers and brakes

Table 6: The industries at long-term risk of carbon leakage

NACE	Industry
154	Manufacture of vegetable and animal oils and fats
201	Sawmilling and planing of wood; impregnation of wood
2112	Manufacture of paper and paperboard
2122	Manufacture of household and sanitary goods and of toilet requisites
2412	Manufacture of dyes and pigments
2413	Manufacture of other inorganic basic chemicals
271	Manufacture of bricks, tiles and construction products, in baked clay

Source: Copenhagen Economics.

2.4 Sectors of particular Nordic interest

2.4.1 Economic importance of the sectors in the Nordic countries?

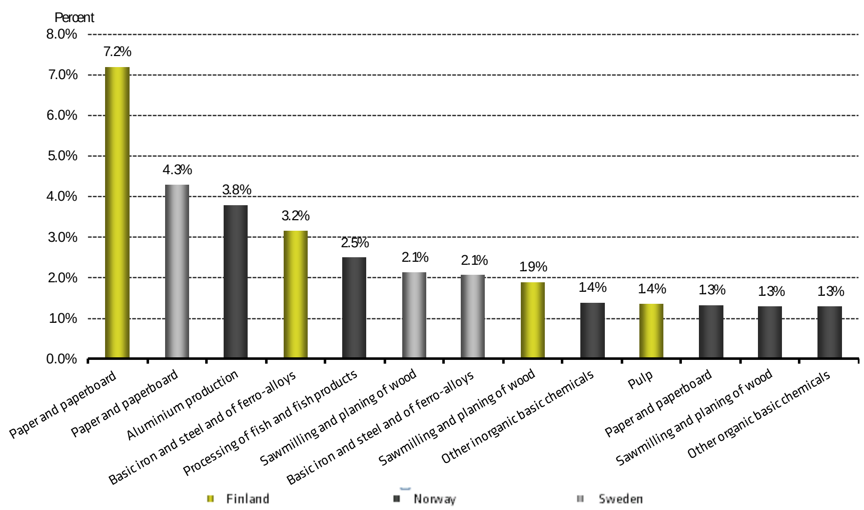
Measures to prevent carbon leakage are not free.[27] It is estimated that the Nordic countries will be able to generate app. €2 billion annually in revenue by auctioning 40 per cent of the total ETS allowances after 2013.[28] Giving away this amount of allowances for free thus constitutes a significant loss of revenue, bearing in mind, however, that such revenues may in fact be illusory over time if climate policy succeeds in reducing the demand for energy. The reason for this is that if production is displaced, demand for energy will decrease and the revenue potential of

[27] See the thorough discussion of efficiency of carbon leakage measures in Chapter 4.
[28] Nordic Council of Ministers (2009)

ETS allowances is reduced.[29] In order for policy makers to introduce expensive carbon leakage measures efficiently, it is important to know what the gains are to the economy of ensuring that production does not move abroad.

Of the industries determined to be at risk of carbon leakage in *both the long and short run*, it is primarily sectors related to paper and pulp industry (paper and paperboard, sawmilling, and pulp), iron and steel, aluminium, processing of fish, and chemicals that have a large importance in the Nordic economies, cf. Figure 9. We will refer to these industries as the *key leakage industries*.

Figure 9: Economic importance of leakage industries



Note: Value added as a share of total value added in manufacturing is calculated on a national level, and is not aggregated across the Nordic countries. No industry in Denmark on the net list has a share of value added that exceeds 1 per cent.

Source: Copenhagen Economics based on Eurostat.

The paper-related industry is the key leakage industry in both Finland and Sweden, where paper and paperboard, sawmilling, and pulp are responsible for more than 10 per cent of national value added in manufacturing in Finland and 7.5 per cent in Sweden. Moreover, iron and steel is also important, constituting 3.2 per cent and 2.1 per cent of value added in Finland and Sweden respectively. The industrial structure in Norway is somewhat different, where the key leakage industries are alumin-

[29] In this context it is very important that foregone revenue estimates are based on realistic long term price elasticities which take into account that production will be displaced.

ium, processing of fish, chemicals, but also paper and paperboard, and sawmilling. These industries are responsible for a total of 12.7 per cent of Norwegian value added. The industries included in the net list are not significantly economically important in Denmark. The share of value added for all industries deemed at risk of leakage in the Nordic countries is listed for all countries in the appendix.

Two additional observations can be made from Figure 9. *Firstly*, some industries deemed to be at risk of carbon leakage are more important to the economy than others. This suggests that if carbon leakage is sought prevented in order to protect domestic production and value creation, the industries listed in Figure 9 may give more bang-for-the-buck. *Secondly,* several industries at risk of leakage are present in more than one Nordic country. This suggests that leakage could in fact take place between the Nordic countries as a response to unilateral carbon taxation, since the underlying structures of these industries are evidently present.

2.4.2 Are some of these sectors only important to the Nordic countries?

The determination, by the European Commission, of industries considered at risk of carbon leakage has been constructed from a rules-based quantifiable approach supplemented with qualitative analysis where deemed appropriate. It cannot be ruled out that such qualitative analysis in the future may to some extent be inspired by Member States' interests. In this context, it is important for Nordic policy makers to know how the industry structure in other Member States may overlap with the Nordic industry structure.

Industries such as manufacture of aluminium, processing and preserving of fish and fish products, iron and steel, chemicals, and paper related production are the key Nordic industries at risk of leakage, cf. Figure 9. Except for organic chemicals, and iron and steel production, these industries primarily have an importance in East European countries, Greece, and Portugal, cf. Table 7. Organic chemicals are important in Belgium, Ireland and the Netherlands, while iron and steel are important in a large amount of other EU countries.

Table 7: Importance of Nordic industries in other EU countries

NACE	Industry	Important in these EU countries
152	Processing and preserving of fish and fish products	Latvia, Lithuania and Estonia
2010	Sawmilling and planing of wood; impregnation of wood	Austria, Latvia, Estonia, Lithuania and Romania
2111	Manufacture of pulp	Portugal
2112	Manufacture of paper and paperboard	Austria, Portugal, Slovakia and Slovenia
2413	Manufacture of other inorganic basic chemicals	None
2414	Manufacture of other organic basic chemicals	Belgium, Ireland and Netherlands
2710	Manufacture of basic iron and steel	Belgium, Bulgaria, Czech Republic, Germany, Greece, Spain, France, Italy, Hungary, Austria, Poland, Romania, Slovenia
2742	Aluminium production	Greece

Note: Note that data is incomplete for a few countries, namely: Czech Republic, Estonia, Ireland, Cyprus, Latvia, Malta and Slovakia.The selection criteria for deeming an industry important in another EU country is if it adds more than 1 per cent of national value added.

Source: Copenhagen Economics based on Eurostat.

3. Estimating carbon leakage

In this chapter we summarise some findings in the literature on carbon leakage. Particularly we underline that leakage estimates tend to vary across both different assumptions and more underlying methodological approaches. We also run our own illustratory model simulation using a linearised partial equilibrium model, and estimate the leakage rate to be at or above 100 percent for the Nordic industries at the highest risk of carbon leakage. A key explanation of this result is that the Nordic countries have a very low rate of carbon input in electricity production and a high level of energy efficiency in manufacturing firms' production as well as high conversion rate in fossil fuel based power plants.

3.1 Existing empirical research

3.1.1 Overview of carbon leakage rates in existing studies

Carbon leakage has gained much attention recently. However, estimates of leakage rates have varied across studies from largely negligible leakage rates, to rates over 100 per cent.[30] Part of the difference can be attributed to different choices of elasticities and deep parameters in different models. However, there are also several structural choices that can tell us something about the expected result. We have identified five elements that will tend to influence model results: 1) Scope of area with joint carbon pricing, 2) Size of price differential between regions, 3) Sector aggregation, 4) Degree of substitution, 5) Modelling total economy or individual sectors.

Scope of area with joint carbon pricing

While several different policy areas[31] have been studied in the literature, there has been a focus on especially carbon pricing in Annex I countries and the EU respectively. Much less focus has been given to smaller policy areas such as e.g. single countries with unilaterally high carbon pricing. Models do however show a very clear trend; the smaller the policy area

---

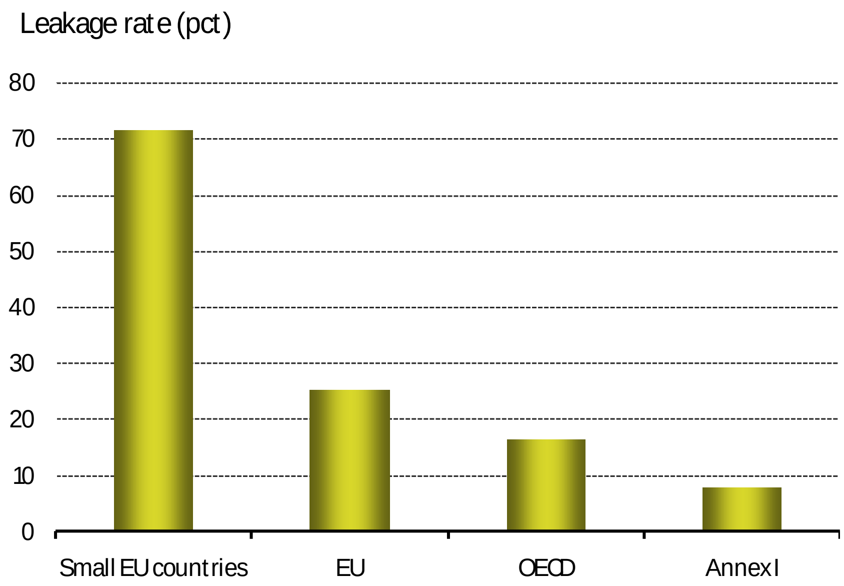
[30] Leakage rates above 100 per cent are found in the literature and occur due to specific assumptions. See e.g. Babiker (2005) where a leakage rate of 130 per cent is found for EU by assuming homogenous goods and imperfect competition.

[31] Defined as regions with a common carbon pricing policy.

the higher the leakage rates become Figure 10. By including more regions into the policy area the price differential between these regions is removed and thus fewer leakage opportunities exist. This argument becomes obvious when considering including a country such as China in e.g. the EU ETS. In such a case, the competitiveness of e.g. Chinese steel production would become more in line with EU producers, which consequently would reduce leakage.

When the policy area is increased, carbon leakage also changes character. While industry leakage is the most important channel for small policy areas, rebound leakage becomes increasingly important as the policy area's impact on the global energy demand is increased.

Figure 10: Leakage rates depending on region size



Note: We have included models that consider all sectors (not just one sector). Different models use different assumptions, and the presented results should be seen in this perspective. We have also applied an element of subjective judgement in order to make the results comparable. We have e.g. omitted the high leakage rates found by Babiker (2005) since these are derived from a homogenous good assumption. Instead Babiker's (2005) lower results assuming differentiated goods (Armington goods) have been included.

Source: Copenhagen Economics based on CPB (2011a), CPB (2011b), Antimiani et al. (2011), OECD (2009), Bohlin (2010), Babiker (2005), Burniaux & Martins (2000), Böhringer et al. (2010), Gerlagh & Kuik (2007), Kuik & Gerlagh (2007), Burniaux & Truong (2002), Copenhagen Economics (2011).

Size of price differential between regions

There are strong reasons to believe that leakage rates will be strongly influenced by the size of the carbon price differential. As argued in Chapter 1, small price differentials may have a large effect in markets dominated by easy-to-transport commodities with single world market prices such as e.g. sugar, aluminium, electronics etc. For such industries, a small carbon price differential can cause all production to close down. Technically this means that the leakage rate will be very high in the short run, and that it will not increase by much for carbon prices exceeding the initial increase. However, for industries dominated by heavy, differentiated goods, leakage may not occur until the price differential has exceeded a certain threshold. Consider for example the cement industry: Since cement (and most other goods) is cheaper to transport by boat than by road, coastal areas will be more exposed to competition than in-land areas. Studies show that there is a significant price difference between such areas.[32] This means that for a relatively small carbon tax in a policy area, only coastal cement production will be leakage exposed. This holds true until the carbon price reaches a level where foreign production can be competitive even in in-land areas.[33] This suggests that if models do not consider such "tipping points" in the carbon price, they may underestimate leakage exposure.

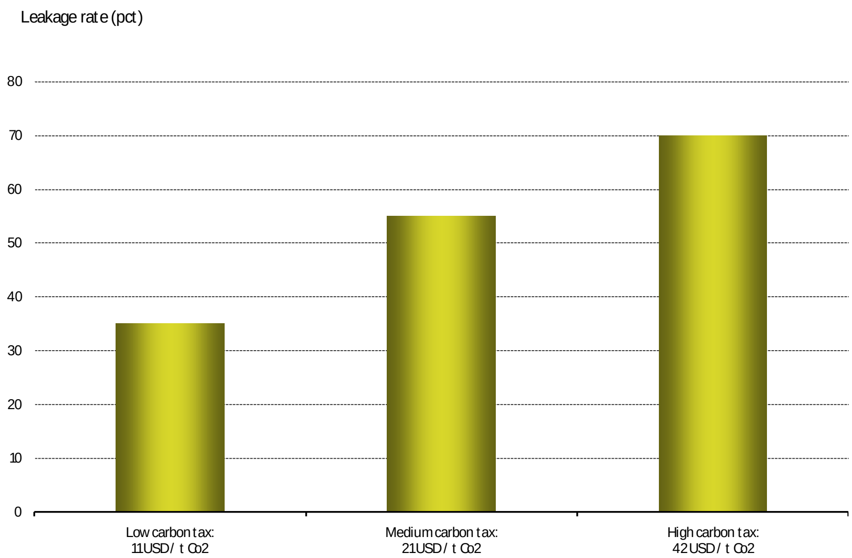
There are not many studies that explicitly consider this point. One study, considering the iron and steel industry in an EU/Japan common policy area finds, that while the leakage rate is 35 per cent for a carbon tax of 11 USD / t CO_2, the leakage rate increases to 55 per cent and 70 per cent for carbon taxes of 21 and 42 USD / t CO_2 respectively, cf. Figur 11.[34] This implies that the rate of carbon leakage increases in the carbon price, implying that production may dissolve at a much faster rate when carbon prices reach a sufficiently high level.

[32] See Walker (2006).

[33] See e.g. Ponssard and Walker (2008).

[34] The authors also find that the carbon leakage rate is increasing over time.

Figure 11: Leakage rates depending on level of carbon tax



Note: Iron and steel industry when EU/Japan for a carbon price differential between EU/Japan and the rest of the world.

Source: Copenhagen Economics based on Gielen & Moriguchi (2002).

Sector aggregation

Sector aggregation matters for leakage rates in the same way that it matters for defining industries at risk of leakage, namely by averaging out sector specific leakage rates when considering more aggregate industries. Most studies, based on general equilibrium models, do indeed not isolate specific industry sectors (or subsectors), as underlying databases are not disaggregated enough.[35] Some studies have found that the rather modest leakage rates coming out of general equilibrium analysis might, at least partially, be explained by the high level of sector aggregation. Leakage rates are more pronounced in highly carbon-intensive sectors, but these effects may be drowned out in very large aggregate sectors.[36] This suggests that even though the leakage rates predicted in most models may be modest, carbon leakage may be substantially higher for single subsectors. This in turn may also imply that leakage at macro level is higher than suggested by models using a too aggregated approach.

---

[35] See e.g. IEA (2008b).

[36] See e.g. Warwick & Wilcoxen (2008) and Fisher et al. (2010), cited in Rutherford (2010).

Degree of substitution in international trade

There is evidence that consumers do not always see imported goods as perfect substitutes for domestically produced goods.[37] This can have several reasons, e.g. that consumers have more information on environmental and ecological regulation of domestic groceries than foreign groceries, or if consumers want to support domestic producers etc. In models, this is captured by the so-called Armington elasticities. Such elasticities imply that the loss in demand and market shares by increasing prices domestically is lower than if foreign goods had been perfect substitutes.[38]

Even though the Armington specification may be appropriate for several types of goods, it is less appropriate for commodity-goods which tend to be much more homogenous than for example locally grown vegetables. Examples of commodities are refined oil, chemicals, aluminium, steel and other metals, rubber, paper, and even food products such as sugar, spices, and to some extent wheat. Such products are traded around the world at very small price differentials. This means that producers cannot pass on local carbon taxes to consumers without losing significant market shares, which leads to carbon leakage. Even though this is the case, most models continue to use Armington elasticities even for commodities such as chemicals and aluminium. This will tend to underestimate carbon leakage for homogenous goods, which does not become less important considering that several of the homogenous goods have very energy-intensive production processes. In fact, a study has shown that changing this specification can increase the leakage rates dramatically from 20-25 per cent to 60-130 per cent, cf. Table 8.

Table 8: Homogenous and differentiated goods

Region with climate policy	Good characteristic	Degree of competition	Leakage rate (pct)
OECD	Homogenous good	Imperfect competition	130
OECD	Homogenous good	Perfect competition	60
OECD	Differentiated good	Imperfect competition	25
OECD	Differentiated good	Perfect competition	20

Note: The leakage rate increases when competition is imperfect. This is due to the effect that under imperfect competition there is not produced enough of the good. When the competitiveness of the monopolised industry is reduced by a carbon tax, the level of competition is increased which leads to an increase in the production of the good and hence an increase in emissions in low-carbon tax regions.

Source: Copenhagen Economics based on Babiker (2005).

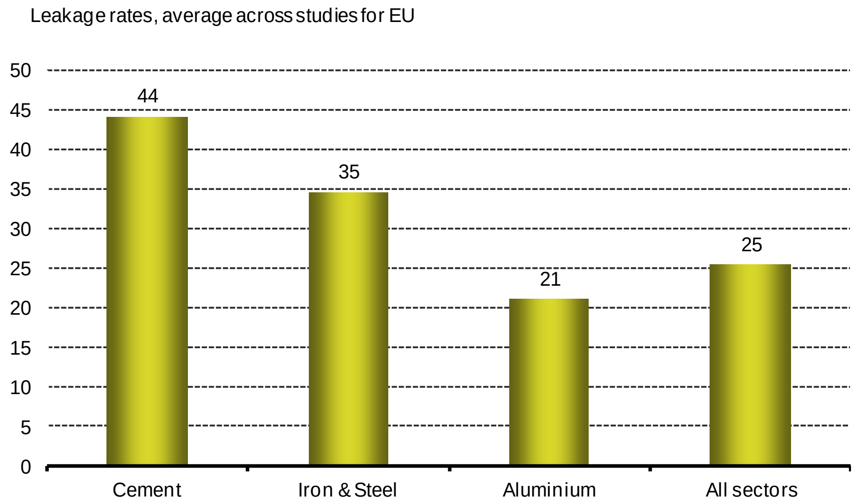
[37] This translates into a substitution elasticity between domestic and imported goods that is not infinite.

[38] If the goods had been perfect substitutes, even very small price differentials would shift the entire demand to the cheapest product.

Type of model – total economy or sector specific

Leakage rates seem to depend on whether models focus on the total economy (by using e.g. general equilibrium models) or have a more sector-specific focus (by using e.g. partial equilibrium models). Data on this issue rather consistently suggest that sector specific studies seem to estimate higher leakage rates than general equilibrium models.[39] This holds true for EU, cf. Figure 12 but also for OECD and Annex I countries, cf. Figure 13. While the average total sector leakage rate for EU is 25 per cent, both the cement and iron and steel sector have leakage rates above this. In fact some studies find that the leakage rate for EU cement can be as high as 70 per cent[40] and as high as 75 per cent for iron and steel.[41] The only result available for EU aluminium seems to suggest that the leakage rate is 21 per cent.

Figure 12: Sector specific and total economy results, EU



Note: The figure depicts leakage rates that have been averaged across different studies. 4 studies were found on cement, 4 on iron & steel, 1 on aluminium, and 3 on all sectors.

Source: Copenhagen Economics based on CPB (2011a), OECD (2009), Böhringer et al. (2010), Ponssard & Walker (2008), Monjon & Quirion (2009), Demailly & Quirion (2006), Demailly & Quirion (2008a), IEA (2008a) and Ritz (2009).

---

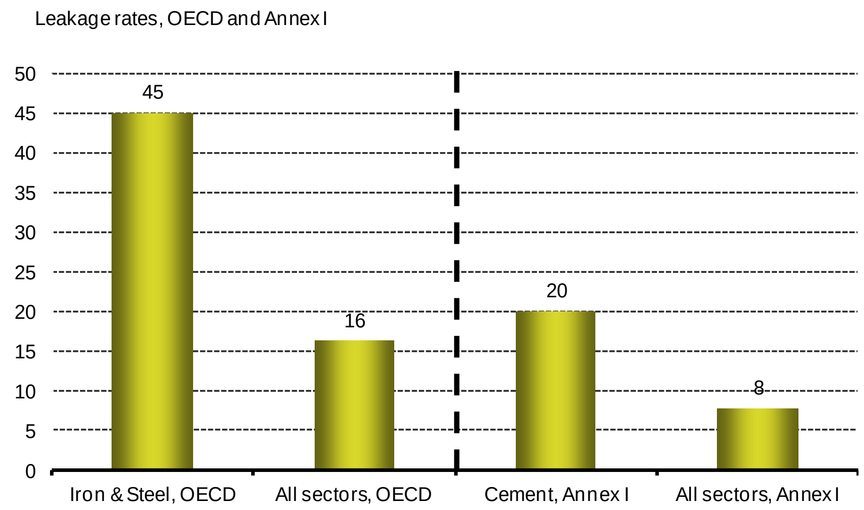
[39] This is also a point made in the literature by e.g. Rutherford (2010).

[40] Ponssard and Walker (2008).

[41] Ritz (2009).

Fewer sector-specific studies are available for OECD and Annex I countries, but the available evidence seems to convey the same conclusion: that leakage rates for specific sectors may be substantially larger than total economy estimates suggest, cf. Figure 13.

Figure 13: Sector specific and total economy, OECD and Annex I



Note: The figure depicts leakage rates that have been averaged across different studies. While 5 studies were used to calculate Annex I all sectors, 3 were available for OECD all sectors, and only 1 for iron & steel OECD, and cement Annex I respectively.

Source: Antimiani et al. (2011), OECD (2003), OECD (2009), Burniaux & Martins (2000), Demailly & Quirion (2008b), Gerlagh & Kuik (2009), Burniaux & Truong (2002), Babiker (2005), Kuik & Gerlagh (2003).

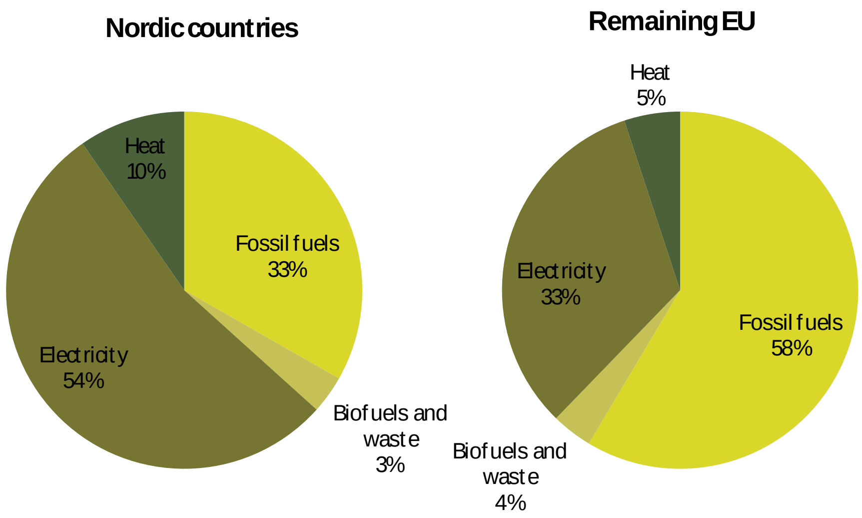
3.2 Our approach to estimate carbon leakage

We base our carbon leakage estimate on the simulation of a partial equilibrium model, which has the advantage of providing a simple and intuitive explanation for the level of carbon leakage. An important input in this model is the net CO_2 emissions in the sectors most at risk of carbon leakage, cf. chapter 2. In the model simulation in Section 3.3, we find that leakage rates of the Nordic industries at risk of leakage can be very large, and exceed 100 per cent. There are several reasons for this: 1) Nordic industries are more energy efficient, 2) Nordic industries consume a relatively higher share of electricity and biofuels as energy input, and 3) the indirect emissions from the production of electricity are very low in the Nordic countries. The remainder of section 3.2 is focused on elaborating these claims.

3.2.1 Importance of electricity in Nordic industries

Electricity is a widely used source of energy in the Nordic countries. While electricity constitutes only 33 per cent of the energy input in an average European manufacturing industry, it constitutes 54 per cent in an average Nordic industry, cf. Figure 14.

Figure 14: Composition of energy consumption

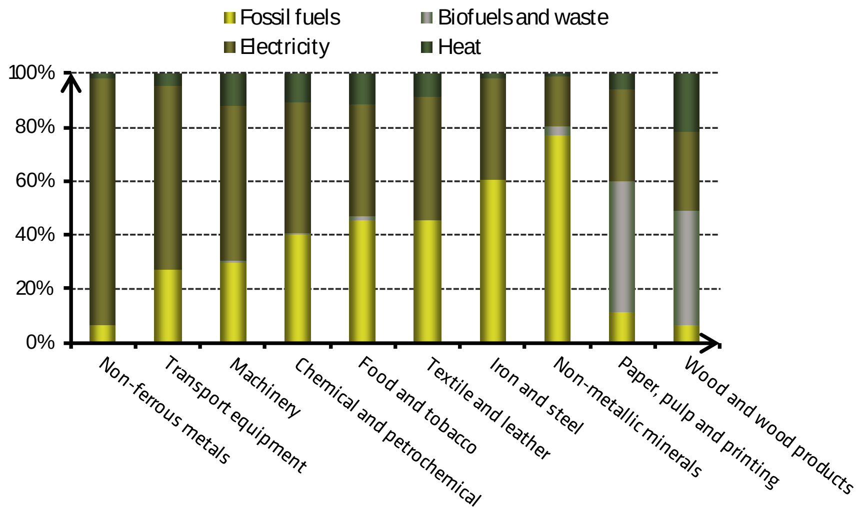


Note: Industries are measured at a NACE-2 aggregation level. Paper, pulp and printing industry has been excluded as it uses exceptionally high amount of biofuels and waste energy sources (89% in Nordic countries and 33% in remaining EU countries). This is most likely due to usage of large amount of wood-related waste products

Source: Copenhagen Economics based on OECD iLibrary- IEA World energy balances

This overall picture however conceals large variation between industries. While electricity is dominant in manufacture of e.g. chemicals, non-ferrous metals (such as aluminium), and machinery, fossil fuel inputs are dominant in especially manufacturing of iron and steel, and non-metallic minerals, cf. Figure 15. Paper, pulp and printing, and wood and wood products consume a significant amount of renewable energy input which is due to the availability of waste products associated with the processing of wood.

Figure 15: Energy consumption per energy type in Nordic industries



Note: Industries are measured at a NACE-2 aggregation level.

Source: Copenhagen Economics based on OECD iLibrary- IEA World energy balances

Due to the large dependence on electricity in Nordic industries, it is important to assess the average CO_2 emissions generated by producing electricity in the Nordic countries. Relative to the remaining EU countries, the CO_2 content in Nordic electricity production is substantially lower. In fact, while the average Nordic CO_2 emissions pr. GWh is 90 t CO_2 (masking a variation from 6 in Norway and 19 in Sweden to 413 in Denmark), the CO_2 emissions pr. GWh in the remaining EU countries is 517 t CO_2 pr. GWh, cf. Table 8. The low share of CO_2 in Nordic electricity is mainly due to a very large share on non-fossil sources of input in electricity production such as hydro, nuclear and other renewable (inter alia wind), cf. Table 9.

Table 9: CO_2 emissions per GWh electricity production, 2007

Country	tCO_2/GWH	Electricity production from			
		Fossil	Nuclear	Hydro	Other renewables
Denmark	413	39%	0%	0%	18%
Sweden	19	2%	45%	47%	4%
Norway	6	1%	0%	98%	1%
Finland	99	8%	7%	4%	75%
Nordic region	90	8%	13%	33%	38%
Remaining EU	517	55%	28%	7%	5%

Source: Copenhagen Economics based on data from CARMA (www.carma.org).

In addition to the low share of fossil fuel in electricity production, Nordic fossil based power plants are relatively energy efficient. This is especially the case in Denmark, where e.g. each unit of coal input into a power plant generates app. 0.43 units electricity/heat compared with 0.37 in the average OECD country, cf. Table 10.

Table 10: Efficiency of electricity production in public electricity and combined heat and power plants

Country	Efficiency of electricity production from Coal	Efficiency of electricity production from Natural Gas	Efficiency of electricity production from Oil
Denmark	43%	45%	40%
Sweden	40%	35%*	37%
Norway	34%	-	30%*
Finland	39%	49%	35%
OECD	37%	45%	37%

Note: The efficiency is calculated as sum of electricity and heat production from public power plant divide by the amount of fuel. The (*) indicates that observations from 1990 were used instead of an average 2001-2005

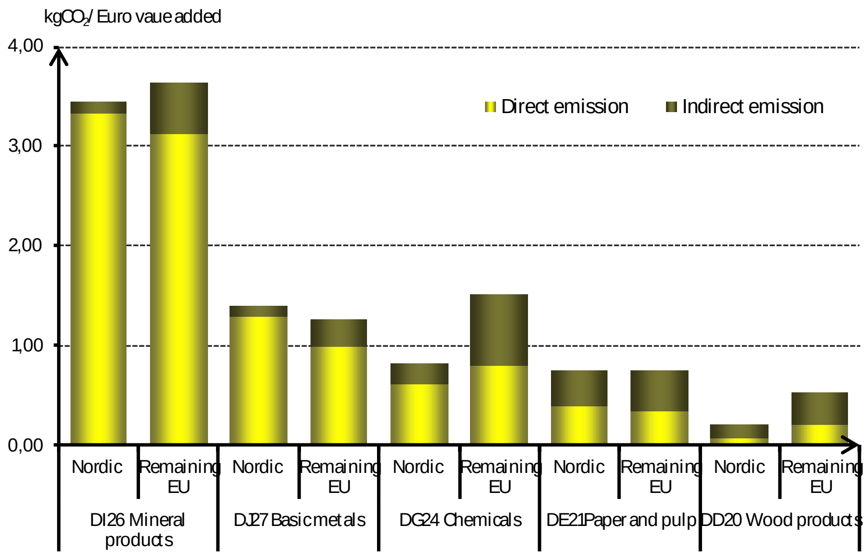
Source: IEA (2008c); Energy efficiency indicators for public electricity production from fossil fuels, IEA information paper

3.2.2 Relative size of CO_2 emissions

We have so far been using energy intensity as our main indicator for carbon leakage risk. Due to variations in energy prices, the fuel mix, and the energy efficiency of production, this indicator does not provide much information on the level of actual emissions. Unfortunately, data on actual CO_2 emissions are not available on a particularly detailed aggregation level. Consequently, we base our assessment on direct CO_2 emissions on a fairly aggregate level, and data on the consumption of electricity and heat.

Based on the aggregate CO_2 data, it turns out that the Nordic industries are relatively more CO_2-efficient than the remaining EU, except in the basic metals industry. This can primarily be attributed to the low CO_2 content of electricity produced in the Nordic countries, since direct CO_2 emissions pr. value added is actually quite high in the Nordic countries, cf. Figure 16.

Figure 16: CO_2 emissions as share of value added at NACE-2



Source: Copenhagen Economics based on Eurostat

In order to run our model simulations on the disaggregated industries which we have identified in Chapter 2, we need to align these data on CO_2 emissions with the NACE-4 level of aggregation used in Chapter 2. The methodology used for this is described in Box 5.

Box 4. Estimation of CO_2-emissions at a NACE-4 level of aggregation

Whereas data on energy purchase is readily available at a NACE-4 level of aggregation, this is not the case for data on the actual consumption of energy.

In order to estimate data for CO_2 emissions at NACE-4 level, we apply some assumptions to the available data. Consider first the available data:

- Data on *direct* CO_2 emissions from combustion of fuels is available at a NACE-2 level of aggregation
- Data on *indirect* CO_2 emissions are calculated based on actual consumption of electricity at NACE-2 level, and the CO_2 content of national electricity production, cf. *Table 8*

This data, which is used in *Figure 16*, are subsequently distributed onto NACE-4 level in proportion to the total energy purchase in order to estimate the emissions of the industries most at risk of carbon leakage. The rather crude assumption is that the fuel mix and energy efficiency does not vary for industries below the NACE-2 level.

The lack of data, and the following assumption, would pose a problem if the objective of this study had been to present a detailed cross sector analysis, with specific leakage rates for specific industries. However, since we present an aggregate measure for the group of industries most at risk of leakage, we do not consider it a course for much concern.

Source: Copenhagen Economics.

Our focus in this exercise is on the industries identified in chapter 2 to be at the most risk of carbon leakage. Narrowing our focus to these sectors reveal that these Nordic industries in fact emit even less CO_2 per value added relative to their EU counterparts. On average for the long run net list, 2.08 kg CO_2 are emitted per euro of value added in the Nordic countries, whereas it is 1.7 times higher if production takes place in the remaining EU. Such differences in carbon-efficiency is a key driver in carbon leakage, and can potentially lead to a leakage rate higher than 100 per cent which implies that overall global emissions increase in response to stricter climate policy.

Table 11: CO2 per value added in leakage industries

	Kg CO_2/ value added	
	Nordic	**Remaining EU**
Net list, short run	2,15	3,75
Net list, long run	2,08	3,63
Gross list	2,36	3,83

Source: Copenhagen Economics based on Eurostat

3.3 Estimated carbon leakage ratio

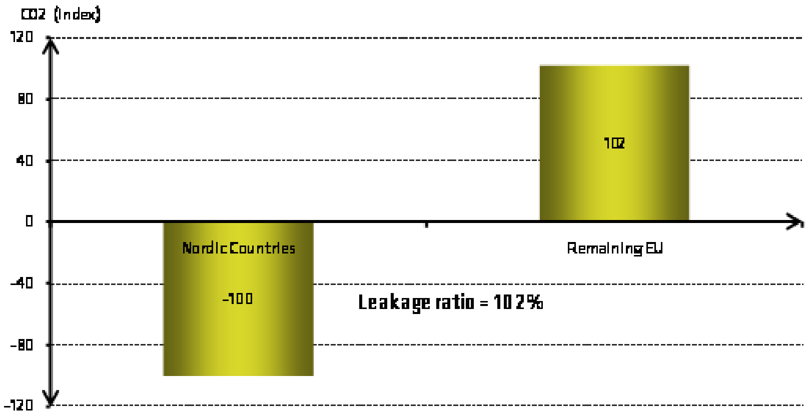
Our simulation results are based on a linearised partial equilibrium model.[42] It has the advantage of being fairly easy to understand and interpret, but this does come at the loss of generality. Such a model is best suited to describe marginal effects around an assumed equilibrium.

Building on the findings of this report, including the industries at most risk of leakage in the Nordic countries and data on both direct and indirect CO_2 emissions, we estimate the leakage rate of the Nordic *key leakage industries* to be 102 per cent, cf. Figure 17. This implies that for every 100 t CO_2 that is abated in the Nordic countries, emissions outside the Nordic countries will increase by 102 t CO_2.[43] This result is primarily

[42] The model specifications are presented in the Appendix.
[43] The model only considers other EU countries.

driven by the high energy efficiency in the Nordic industries, and the low CO_2 content in electricity produced in the Nordic countries.

Figure 17: Carbon leakage for Nordic industries most at risk



Note: The level of abatement is a result of an assumed CO_2 price differential of 33 %. This differential however, has no impact on the leakage rate, since this is assumed linear in the price differential. Even though the Nordics and the rest of EU are covered by the ETS, the implicit CO_2 price differential between these regions is positive. This is because the Nordic countries generally impose higher energy taxes and impose a large subsidy to renewable energy producers through the electricity bill.

Source: Copenhagen Economics based on model simulation

The model results presented above are meant to illuminate and explain the existing effects. Our conclusion is that a large number of studies tend to underestimate the size of leakage, particularly from a long term perspective. In line with other studies focused on core leakage sectors, we do estimate the leakage ratio to be at around, and even exceeding, 100 % by a small margin. Moreover, the model simulations are based on an assessment of carbon leakage between the Nordic countries and the rest of EU. While the EU constitutes a very large trading partner for the Nordic countries, leakage to third countries is a real and growing concern. Since several large non-EU countries have an even higher CO_2-content per value added, we expect carbon leakage rates to be even higher when comparing the Nordic countries with non-EU countries.

Nordic leakage exposed industries tend to consume most of their energy demand as electricity from the grid, while similar firms in other EU countries tend to produce more of their own energy based on fossil fuels. Moreover, fossil based power plants in Nordic countries are relatively efficient. Therefore, every unit of energy intensive production moved from the Nordic area to other parts of EU, or other parts of world, are likely to be followed by a net increase in carbon emissions. This may in fact drive carbon leakage rates above 100 per cent, if demand is not very price elastic.[44] Partly this could be offset by increased exports of "clean" electricity to other EU countries, but due to the relatively limited grid infrastructure in Europe, that would only be feasible through costly grid upgrades. An analysis of this perspective in greater detail would require a specific power market model to capture electricity trade within and outside the region, including decisions to increase or decrease capacity in different types of power generation (atomic power, wind mills, hydro, coal and gas plants). That goes well beyond the sphere of this project.

[44] In this case, consumers would reduce demand significantly, thus not giving incentive to build up foreign supply (which is marginally more expensive – otherwise it would have been consumed in the first place)

4. Policy recommendations

Industries in the Nordic countries are heavily exposed to carbon leakage, as documented by Chapters 2 and 3. The question we address in Chapter 4 is: what is the appropriate policy response to this challenge?

Firstly, we recap the characteristics of existing, and discussed policy options to deal with carbon leakage (section 4.1 "Basic recap of policy options"). *Secondly*, we review how these policy options score on a number of success criteria that we set up for such measures from both a theoretical as well as more practical level (section 4.2 "Evaluating anti-leakage measures"). *Thirdly*, we provide our overall recommendations for the course of action to be taken by Nordic countries in national, Nordic, EU, and global perspectives (section 4.3 "Overall policy recommendations").

4.1 Basic recap of policy options

There are currently a wide range of measures in place in Nordic and EU countries to reduce the extent of carbon leakage. Our focus in this report is on measures that are relevant in a wider Nordic and international policy context and relevant in particular for the discussion of the climate policy framework after 2012.

The EU has provided a framework that directly regulates measures to reduce industrial carbon leakage. Specific regulation is designed in the EU ETS (allocation of free allowances) and the EU Energy Tax Directive (application of reduced rates of energy taxes). Compensating industries for high electricity costs is addressed under the EU State aid rules and new guidelines for this is currently being contemplated.[45]

There are discussions at the more global level about other types of policy options. Two options that have been discussed quite heavily are border tax adjustment mechanisms (BAMs) and sector based Clean Development Mechanisms (sector CDM).

[45] See e.g. http://ec.europa.eu/competition/consultations/2011_questionnaire_emissions_trading/index_en.html

Before we evaluate the effectiveness and efficiency of such measures in section 4.2, we go through the main characteristics of the following policies:

- EU ETS
- Energy taxation and financing of renewable energy investments
- Compensating electricity intensive industry
- Border adjustment mechanisms and sector CDM

4.1.1 EU ETS

This focus of this section is on the post-2012 functioning of ETS. Recognising the risk of carbon leakage, industries at risk of carbon leakage are provided with free allowances. The risk of carbon leakage is evaluated based on energy intensity and trade intensity as explained in Chapter 2. The amount of allowances provided to each firm depends on a benchmark established for each industry, i.e. if a firm can use energy more efficient per unit of output, then, in principle, it receives more allowances than it needs to serve its current level of production, cf. Box 5. The actual amount of allowances is based upon the historical production within the activities. The continued allocation of allowances is conditional on continued production, and new entrants will be provided with allowance from a reserve pool according to a benchmark basis. Industries at risk of carbon leakage receive 100 per cent free allowances according to the benchmark, while other industries receive 80 per cent free allowances according to this benchmark in 2013, gradually decreasing to 30 per cent in 2020.

Box 5. Main elements of EU Emission Trading System

The ETS now operates in 30 countries (the 27 EU Member States plus Iceland, Liechtenstein, and Norway). It covers CO_2 emissions from installations such as power stations, combustion plants, oil refineries, and iron and steel works, as well as factories making cement, glass, lime, bricks, ceramics, pulp, paper, and board.

Nitrous oxide emissions from certain processes are also covered. Between them, the installations currently in the scheme account for almost half of the EU's CO_2 emissions and 40% of its total greenhouse gas emissions. Air transport will join the scheme in 2012. The EU ETS will be further expanded to the petrochemicals, ammonia and aluminium industries, and to additional gases in 2013, when the third trading period will start

During the first trading period (2005 to 2007), Member States have auctioned only very limited quantities of carbon allowances, and also during the second trading period (2008 to 2012) the lion's share of carbon allowances is still allocated for free. From the start of the third trading period in 2013 about half of the allowances are expected to be auctioned.

The revision of the Emission Trading Directive, agreed on 17 December 2008, foresees a fundamental change from the third trading period starting in 2013. Auctioning of allowances will be the rule rather than the exception. No allowances will be allocated free of charge for electricity production, with only limited and temporary options to derogate from this rule. Sectors and subsectors found to be exposed to a significant risk of carbon leakage will receive allowances for free, based on benchmarks, but for non-exposed industries such allocations will gradually be phased out. These rules imply that as from 2013 at least half the total number of allowances is expected to be auctioned.

Free allowances will in principle be allocated based on product-specific benchmarks for each relevant product. The starting point for the benchmarks is the average of the 10% most efficient installations, in terms of greenhouse gases, in a sector and they shall take into account the most efficient techniques, substitutes, and alternative production processes.

The benchmarks will be multiplied by a historical production figure, and some other factors that are needed to ensure the respect of the annually declining total cap.

Free allowances will be product-based, not sector-based, which implies that all products of the same kind get an equal treatment in terms of carbon leakage. All relevant products will be classified as exposed to carbon leakage or not, based on the list of sectors.

Source: Copenhagen Economics based on European Commission, DG Climate Action.

Energy taxation and financing of renewable energy investments

The EU Energy Tax Directive (ETD) allows Member States to apply reduced tax rates to firms at risk of carbon leakage, though with somewhat different criteria for determining risk of leakage than the revised ETS. This is, however, proposed to be streamlined in the proposed new ETD (new approach). Moreover, in the new approach, products at risk of carbon leakage may be totally exempt from the CO_2 tax element, but for the energy tax element, reductions in tax rates may not fall below the specified minima rates, cf. Table 12

Table 12: Dealing with leakage in EU legislation

	Energy Tax Directive		EU ETS
Old approach	Energy volume based taxes Tax exemption if industry is energy intensive		Free allowances to nearly all producers
New approach	Energy content tax Tax reduction (to minimum rate) if industry is energy intensive	CO_2 tax Tax exemption if products are at risk of carbon leakage (uses same definition as EU ETS)	Free allowances, based on a benchmark to products that are at risk of carbon leakage

Source: Energy Tax Directive and EU ETS Directive.

The proposed ETD also intends to improve consistency in the coverage of emissions vis-a-vis the ETS. First, it proposes zero taxation of fossil fuels when used by installations that are covered by ETS. Second, it proposes that energy production in installations which falls below the production thresholds for inclusion in the ETS should be covered by the ETD. The minimum rates should in this case be equivalent to the expected price of ETS allowances. So to put it simply; the proposed ETD deals with both the previous problems of overlapping regulation, and the gap in regulation.

In some countries renewable energy investments are financed through an extra charge on electricity prices. In the Nordic countries where this is the case, there are provisions allowing for reduced rates for energy intensive firms. The extent of the reductions varies across the countries, where leakage exposed industries in Sweden e.g. are not obliged to buy green certificates.[46]

[46] Energimyndigheten (2010) – Åtgärder för at skydda elkunden mot höga elcertifikatpriser

4.1.2 Compensating electricity intensive industry

In the ETS directive, financial compensation to electricity intensive industry is foreseen regulated through EU State aid rules. The guiding principles for granting financial support to electricity intensive companies is currently rather vaguely defined, and is not necessarily in line with the definition of industries at risk of leakage as defined by the ETS directive. Currently, however, the Commission is revising the State aid Guidelines related to the ETS inter alia based on a consultation process which ended in May 2011.

4.1.3 Border tax adjustment mechanism and sector based CDM

In the context of global climate change negotiations, two types of anti-leakage measures have been at the forefront. They are both directed primarily at countries/regions who do not have binding emission reduction targets and who are not involved in carbon trading. The premise is that the marginal price of carbon reductions in such countries e.g. China and India, is well below producers in countries with ambitious emission reduction targets such a number of OECD countries.

The *first* such measure is the Border adjustment mechanism. This is an issue that has been widely discussed in both EU and the US especially in relation to international climate negotiations. Essentially, it boils down to domestic producers being refunded an estimated carbon tax when they export and/or while importers will have to pay a charge corresponding to the estimated carbon content of the products. The products to be levied import duties would come from countries with no binding emission reduction targets. Instead presumably, countries with firm targets would be exempt. Such measures have not yet been implemented in any country or region.

The *second* measure is the sector based CDM. It would apply to a whole, typically energy intensive, industry such as production of steel or aluminium. The sector as a whole would have to commit to reductions of emissions (and/or energy-use) within the sector beyond an agreed baseline. The definition of the baseline is inherently difficult in general, but some robustness can be defined in industries that use known best-practices and technologies which are also used world-wide. The mechanism may reduce leakage by forcing countries with non-binding countrywide targets to implement energy/CO_2 saving technologies with equivalent effect on their total production costs as for example the EU's ETS system.

4.2 Evaluating anti-leakage measures

The "anti-leakage" measures are evaluated against a list of four success criteria:

- Ability to stem leakage while maintaining incentives to reduce emissions
- Cost-benefits considerations from a public finance perspective
- Administrative feasibility in practice
- Conformity with EU internal market and WTO provisions

4.2.1 Ability to stem leakage while maintaining abatement incentives

The purpose of carbon policies is to provide incentives to reduce emissions in a cost effective manner. The purpose of "anti-leakage" measures is to stop/reduce movement of emission-intensive activities from the region with high carbon prices to regions with lower.

The first success criterion we review is the ability to score high on these two criteria. This will be achieved by providing incentives to maintain production within the high carbon price area while maintaining incentives to save CO_2 emissions.

The EU ETS post 2012 has generally been recognised as being much more targeted in dealing with carbon leakage than the ETS pre 2012. The grandfathering principle used in the period 2005 to 2012 implied that nearly all firms that were directly impacted by the scheme received free allowance whether or not they were leakage exposed. The post 2012 regime limits free allowances to industries identified at risk of leakage and is thus more targeted. Moreover, allocation of allowances is based not upon the firms' own level of actual emission (as was the case prior to 2012) but on best practice emission per unit of output within the industry.

Finally, the continued allocation of allowances is conditional upon continued production. Based on this, the ETS post 2012 provides incentives to maintain production inside the EU region while exposing the firm to full marginal incentives to save CO_2.

This is a very important issue: providing free allowances by itself does not prevent leakage: it is simply a lump sump transfer. Only by linking the continuing receipt to continuation of the emission related activity, the measure will reduce leakage.

The one caveat we note is that variations of production within some margins do not lead to reductions in the number of allowances. So there are some incentives to cash in free allowances and cut production down to the level where the amount of allowances will be reduced. But besides from this point, the system scores overall good marks on both success criteria.

Energy taxes and financing of renewable energy. Both the existing ETD and national rules for financing of renewable energy for power generation in Denmark, Norway, and Sweden provide for reduced/zero rates for energy intensive industries. Neither have specific considerations with regard to actual or potential trade intensity. The reduced/low rates should reduce carbon leakage, however at the cost of removing at the same time marginal incentives to reduce emissions. The proposed ETD from 2011 proposes to extend the principles of ETS for leakage-exposed industries to the CO_2 element of the tax, which has two advantages: more targeted support to industries actually at risk, and maintaining incentives to abatement. However, the proposed ETD will preserve the existing approach to reduced rating for the energy tax part, which in many countries will be by far the largest component of overall taxation. So the overall mark for dealing with leakage in energy taxes is middle to low for mitigating leakage and low for maintaining incentives to produce.

Border tax adjustment will ensure in theory that exported goods have no costs of carbon embodied while imported goods embody the full internal costs of carbon. However, it will also imply that exporters to regions with low carbon costs have no reason to adopt carbon saving technologies. The consequence of that depends on the importance of such regions and such products in global production and trade. Moreover, the effectiveness of such a measure depends crucially on the ability to assess the carbon content of specific goods and the origin of the "added carbon". In a globalised production chain it is relatively easy to circumvent a carbon import tariff by e.g. performing the carbon intensive part of the process in a low carbon cost country and then manufacturing the remaining product in a high carbon cost country for the purpose of exporting to a country with a carbon import tariff. In trade statistics, it is possible to assess which country that provides value added to a product in different stages.[47] However, since the "carbon added" is not necessarily equal to the value added, trade statistics serve as little help in this respect. In principle BAMs should score high on mitigating carbon leakage, lower than the newly adopted ETS in preserving incentives for carbon preservation for exporters, but higher through its ability to provide abatement incentives for importers.

A well-designed credit mechanism, such as the Clean Development Mechanism will in theory reduce carbon leakage. The basic driver is that it reduces the price of ETS allowances and hence the difference between carbon prices inside EU, the nearly monopoly buyer of CDM projects globally, and in non-Annex B countries. From a global climate policy perspective the key issue of CDM is whether it delivers "additionality".

[47] This is not without problems though, and several studies point out problems with measuring value added in trade statistics.

However, for industrial leakage more specifically the beauty of targeted sector CDM is that it may raise carbon prices in the industries that are trade exposed in developed countries. Thus well-targeted sector based CDM may offer substantial attractions for developed economies, indeed also to make it more acceptable to impose stringent climate policies.

In practice, the current CDM system has been accused of actually increasing carbon leakage. A reduction in emissions in non-Annex B country due to a CDM credit is a substitute for an emission reduction in an Annex B country, where this reduction is generally more expensive. Hence a CDM system does not reduce overall global emissions. However, the change in carbon consumption behaviour will affect carbon consumption elsewhere. While the impact of this on global emissions can both be negative and positive, studies have found that net leakage typically is positive, thus leading to an overall increase in global emissions when CDM projects are undertaken.[48]

It is worth underlining the difference between the existing project-based CDM and a new sector based CDM. Both will, for a given reduction target for the EU, reduce the allowance price by moving marginal abatement projects to regions outside ETS. Hence it will also reduce the difference between carbon prices inside and outside the EU and, all other things equal, reduce leakage pressures. But the difference between the two CDM types is that a sector CDM in addition can target leakage pressures more directly by forcing implicit carbon pricing in the targeted sectors in countries competing head-on against EU firms. Most of the CDM project in the existing system, not the least the substantial amount of CDM directed towards non-CO_2 abatement, have had no such direct effects.

Finally an important issue is how important any CDM should be in EU's abatement strategy. There is a substantial logic in suggesting that the share of the EU abatement target reduction that can be reached by CDM projects, should depend on the expected differences between carbon prices inside and outside the EU: if the expected price difference is very high without application of CDMs, then that is 1) an indication of substantial amount of low hanging options to abate outside the EU and 2) higher resulting leakage pressures on energy intensive industries.

4.2.2 Cost-benefit analysis from a public finance perspective

In addition to reviewing the effectiveness of anti-leakage measures, the question should also be asked whether it is worthwhile to prevent leakage from a national and global welfare perspective.

48 Rosendahl & Strand (2011).

In principle, compensating energy intensive industries for the cost of carbon policies implies a loss of revenues needed to be financed by distorting tax rate changes. So in principle there is a trade-off between allocation efficiency in product markets – locating production where it is most efficiently carried out – and public finance consideration. The trade-off may over time be somewhat illusory however: for very footloose industries the revenues to be had by letting them fully pay for their allowances will disappear as they move out. Our illustrative modelling suggests that this is a realistic long term outcome if no anti-leakage provisions are included. The EU ETS system is well functioning in this perspective: keeping energy intensive inside the region in a cap-and-trade system will keep overall energy demand up and hence also overall prices of allowances. If they move out, allowance prices and hence revenue will fall.

According to some studies,[49] policies intended to reduce leakage have little effect on welfare overall – even in the countries implementing them. The explanation for this is that such policies just shift global production in certain energy-intensive goods. Although these welfare changes are small, implementing countries do benefit from adjustment policies, while most non-implementing countries would prefer no adjustment. According to these studies the *net effect* of anti-leakage policies is a slight reduction in the global cost of achieving a given level of emissions reduction.

A recent study[50] compared three anti-leakage measures – output-based rebates, import tariffs and full border adjustment –, and found full border adjustment to be the most effective tool to reduce leakage. However, the differences across anti-leakage measures and the overall appeal of such measures *decline with size of the region in which the policies are applied*. From a strict Nordic perspective, it is a reasonable conjecture that these three anti-leakage measures in practice are equivalent.

So our overall assessment is that there is a good general case from an environmental and national welfare perspective of pursuing targeted policies that contain industrial carbon leakage from the most heavily exposed industries, where revenues from emissions are in any case illusory from a long-term perspective.

The argument for using anti-leakage measures also hinges on the global as opposed to local/national/Nordic character of the environmental objective being pursued. With respect to global warming, the regional source of the emission is basically irrelevant for the size of damage caused: the relevant measure is the accumulated global emissions of CO_2. This is substantially different from addressing local or national environmental damages such as excessive noise and air pollution in con-

[49] See e.g. Böhringer et al. (2010).

[50] Böhringer et al. (2011a).

gested urban areas, or reduction of water quality from excessive use of fertilisers and pesticides. Reducing air pollution in Stockholm or achieving cleaner internal waterways in Norway produce welfare benefits that are not dependent on whether such measures are followed by similar policies in other countries.

4.2.3 Administrative feasibility in practice

Setting up and administrating anti-leakage policies are fraught with compliance costs issues and difficult trade-offs. To provide a few example: providing free allowances to nearly all firms with a compliance obligation (as done with the ETS pre 2012) is more easy to administer than defining and running programmes that define what leakage exposed industries are, and what a meaningful benchmark is for any given industry (ETS post 2012). However, providing free allowances to all instead of using revenues to reduce labour taxes lead to welfare distortions in labour and product markets.

A comprehensive approach to improve administrative feasibility is to deal with carbon leakage consistently through the different instruments that affect firms' energy costs. In other words, the criteria that determines the degree of exposure to leakage and the character of the associated treatment should depend on the specific situation of the industry and not the type of policy instrument that increase the costs of energy use. That is generally not the case to day: the EU's proposed Energy Tax Directive goes some way to improve consistent treatment in the ETS Directive and Energy Tax Directive. This will reduce compliance costs and increase efficiency for both public and private actors, but even if adopted, arbitrary differences would still prevail. Current rules for dealing with financing of renewable energy also lack common guidelines across Member States, and could thus be seen in the same perspective.

We would in particular consider the Border Tax Adjustment mechanism to be difficult to administer and apply in practice. Essentially, it assumes that at the point of entry into the importing region, it is possible to estimate both the carbon content of each product and where the production process, which leads to the emission of carbon emissions, took place. Indeed each of these estimates is fraught with major problems. The *first* issue is difficult since the carbon content of different goods vary according to the specific production process.[51] It may be possible to use e.g. EU best-practice benchmarks for carbon contents, but while this may

[51] See e.g. Nordic Council of Ministers (2010) illuminating that any given production can take place with many different technologies and different efficiency in production. Estimated carbon content of imports can be based on technologies in the country of import but this may not at all be representative of the country of exports.

not be very representative of non-EU countries[52] it lacks the ability to give incentives for producers to increase energy efficiency of their specific production process. The *second* issue is essential as the policy measure is supposed to "punish" only importation of embodied carbon emission from countries with lenient carbon policies. Imposing tariffs on embodied carbon may in general be difficult to apply in trade law since it needs to discriminate among countries. If determined to be in violation of trade law this would limit the coverage of tariffs to a fraction of the total emission embodied in trade, seriously limiting its effectiveness.[53]

4.2.4 Conformity with EU internal market and WTO provisions

The adopted revised ETS Directive and proposed ETD, if adopted, will - by definition - offer a framework for dealing with carbon leakage within EU countries that are legally consistent with EU's internal market rules.

Addressing the energy costs of *electricity intensive* users seems to be the main challenge both within Nordic countries and between EU countries in general. *Firstly*, while ETS Directive and the ETD provide compensation to e.g. energy intensive industries based on fossil fuel input, it provides no compensation to energy intensive industries based on electricity input. *Secondly*, current national compensation schemes to reduce electricity prices to energy intensive electricity users are only being regulated by the EU State aid criteria.

These criteria may not in practice be sufficient to ensure common treatment between Member States and thus give rise to competitive distortions within EU. Consequently, they may not be able to prevent carbon leakage within EU. In order to create a comprehensive EU approach to mitigate carbon leakage, we would suggest that national compensation schemes designed to compensate for higher electricity prices due to the ETS should be governed by the same principles that apply to firms directly affected by the EU ETS. A process in the Commission to adopt specific guidelines addressing such issues within the framework of EU State aid is currently ongoing. Given the importance of electricity consumption for energy intensive industries in the Nordic countries, the outcome of this propose is highly important from both a leakage and Nordic competiveness perspective.

It is possible that BAMs can be designed to be compatible with WTO rules. However, an effective application may in practice turn out to be very difficult.[54] First GATT, and later WTO, rules were designed to deal

---

[52] See e.g. the WTO speech by Pascal Lamy (9/12 2007),

[53] Böhringer et al. (2011b), page 4.

[54] WTO (2011).

with "treatment" of products and services at the border. BAMs, on the other hand, need to look at supply chain based determination of the size and location of the carbon related emissions from the production of the product in questions, as discussed above. Second, while WTO rules allow environmental concerns to be factored into trade policy measures, there is no easy way to compare different sets of mitigation policies, and hence the legality of any import tariff. Hence our conclusion is that BAMs may be a useful instrument to have in reserve to pressure concessions in global climate policy negotiations, but due to its difficulties of being applied effectively in practice, its credibility as a stick in such negotiations may be somewhat limited.

4.3 Overall policy recommendations

4.3.1 General principles

The study has identified a number of industries in Nordic countries with large energy costs that are competing head on in international markets with little or no scope to raise relative prices relative to key competitors. General economic welfare principles suggest that targeted measures to address industrial carbon leakage for such trade-exposed industries are well founded by both theoretical and empirical arguments. We underline in particular, as suggested above, the global character of the negative externality from CO_2 emissions: reducing emissions inside the Nordic area only to it see go up elsewhere by a corresponding amount solves no environmental problems while imposing substantial adjustment costs on the Nordic economy.

In this context, it is important that the chosen measures effectively give incentives to maintain production within the region with higher carbon prices, and at the same time preserve incentives to abatement at the margin. We note that the revised ETS Directive has gone some way to improve this balance, but that the proposed new Energy Tax Directive only goes halfway in this direction. However it is a substantial improvement of the current system.

We also recommend that the underlying criteria and instrumentation for anti-leakage measures are appropriately harmonised across the ETS Directive, the ETD as well as in the practical implementation in national legislation in Nordic and EU countries. This will reduce compliance costs, internal market distortions, and improve efficiency of CO_2 abatement.

The study has also presented results from the carbon leakage literature. One clear observations that can be drawn from this is that the smaller the region, the larger the size of carbon leakage. This has the obvious - but sometimes overlooked - implication that ambitious climate policies are not very effective if they are conducted by a small country/region.

4.3.2 Nordic angles

The industries with the highest risk of carbon leakage in Nordic countries are characterized by a high share of electricity in energy consumption. Neither electricity producers nor electricity-intensive consumers are compensated through free allowances, which leave electricity intensive manufactures at a serious competitive disadvantage. The possibility of compensating such firms nationally is currently guided by the EU State aid rules. Currently, these guidelines are not very adequately specified, however guidelines are currently being contemplated by the Commission. Developing a comprehensive common EU framework that is capable of offering adequate compensation to such firms should be a priority.

The key-industries in the Nordic countries at risk of leakage, except for iron and steel, are relatively less important in the large EU countries. In future definitions of the list of industries at risk of leakage, the Nordic countries should keep in mind that no political capital from large EU countries is likely to be invested to benefit industries that happen to be key Nordic leakage industries.

4.3.3 International/global angles

Transportation costs are a brake to carbon leakage. Increasing transportation cost by e.g. imposing carbon cost on international shipping will not only reduce emissions from shipping but also reduce carbon leakage risks. Increasing the cost of shipping will however – as is the case with border adjustment mechanisms – increase the price of Nordic imports and therefore the production cost of importing firms, thus lowering competitiveness and increasing consumer prices.

More generally, it should actively be pursued to expand the current CO_2 pricing area. While this optimally should take place within the context of UN, this increasingly becomes less realistic within an acceptable timeframe. Alternative trails to pursue could be to seek to include more countries in the EU ETS system, encouraging other bilateral CO_2 pricing areas,[55] or pursuing bilateral climate agreements e.g. as a condition in the granting of development aid or climate aid.

With Nordic countries generally in favour of an open trade environment, the perils of BAMs can hardly be overstated. Such measures may seem useful in theory and as a bargaining tool in international climate negotiations, but the measures will be difficult to apply in practice, hence undermining their effectiveness and thus their deterrence value.

[55] Australia for example has adopted a CO_2 pricing area of its own.

References

Antimiani et al. (2011) - Cooperative and non-cooperative solutions to carbon leakage

Babiker (2005) - Climate change policy, market structure, and carbon leakage

Bohlin (2010) - Climate Policy within an International Emission Trading System - A Swedish case

Burniaux and Martins (2000) - Carbon Emission Leakages - A General Equilibrium View

Burniaux and Truong (2002), GTAP-E, and energy-environmental version of GTAP, Technical paper no 16 www.gtap.agecon.purdue.edu/resources/tech_papers.asp

Böhringer et al. (2010) - The Global Effects of Sub global Climate Policies

Böhringer et al. (2011a) - Cost-Effective Unilateral Climate Policy Design - Size Matters. Resources for the future

Böhringer et al. (2011b) - Embodied Carbon Tariffs.

Congressional Research Service (2008), Carbon leakage and trade issues and approaches, Wikileaks 2008

Copenhagen Economics (2010) – Innovation of Energy Technologies: The Role of Taxes

Copenhagen Economics (2011) – Carbon leakage from Danish energy taxes

Climate Strategies (2007), Differentiation and dynamics of EU ETS industrial competitiveness impacts

CPB (2011a) - Trade and Climate Change

CPB (2011b) - Do border measures affect carbon leakage

Demailly and Quirion (2006), CO_2 abatement, competitiveness and leakage in the European cement industry under the EU-ETS: grandfathering vs. output-based allocation, Climate Policy, 6(1), August, pp. 93-113

Demailly and Quirion (2008a), European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry, Energy Economics, 30, pp. 2009-2027

Demailly and Quirion (2008b), Leakage from Climate Policies and Border Tax Adjustment: Lessons from a Geographic Model of the Cement Industry, forthcoming in Roger Guesnerie and Henry Tulkens, editors, The Design of Climate Policy, papers from a Summer Institute held in Venice, CESifo Seminar Series, Boston: The MIT Press

Energimyndigheten (2010) – Åtgärder för at skydda elkunden mot höga elcertifikatpriser

Energy Tax Directive: 2003-96-EC, restructuring the Community Framework for the taxation of energy products and electricity

ETS Directive: Commission Decision of 24 December 2009 determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage. Document C (2009) 10251

Fisher et al. (2010), Carbon policies, competitiveness and emissions leakage: An international perspective, Resources for the future Conference Summary

Gerlagh & Kuik (2007), Carbon leakage with international technology spillovers

Gielen and Moriguchi (2002), CO_2 in the Iron and Steel Industry: an Analysis of Japanese Emission Reduction Potentials. Energy Policy, 30 : 849-863

Hoffmann (2004), Asian countries’ specialization in different maritime businesses: Challenges and opportunities arising from the process of concentration in shipping. UNCTAD Working Paper

Hourcade et al (2007) - Differentiation and dynamics of EU ETS Industrial Competitiveness Impact- Climate Strategies Report

IEA (2005), Industrial Competitiveness

IEA (2008a), Climate Policy and Carbon Leakage, Impacts of the ETS on Aluminium

IEA (2008b), Issues behind competitiveness and carbon leakage

IEA (2008c), Energy efficiency indicators for public electricity production from fossil fuels, IEA information paper

IPCC (2007): Mitigation of climate change. IPCC Fourth Assessment Report. Cambridge and New York: Cambridge University Press

Kuik and Gerlagh (2003), Trade Liberalization and Carbon Leakage, the Energy Journal 24: 97-120

McKinsey and Ecofys (2006), report on international competiveness

Monjon and Quirion (2009) - Addressing leakage in the EU ETS - Results from the CASE II model

Nordic Council of Ministers (2009) – EU Emission Trading – Economical Effects of Emission Auctions

Nordic Council of Ministers (2010) – Global Carbon Footprint. Methods and import/export corrected results from the Nordic countries in global carbon footprint studies

OECD (2003) - Environmental Policy in the Steel Industry: Using Economic Instruments. NonClassifié COM/ENV/EPOC/DAFFE/FCA (2002)68/FINAL

OECD (2009) - The Economics of Climate Change Mitigation Policies and Options for Global Action Beyond 2012

Ponssard and Walker (2008) – EU emissions trading and the cement sector. A spatial competition analysis

Ritz (2009) – Carbon leakage under incomplete environmental regulation - an industry-level approach

Rosenthal & Strand (2011) – Carbon Leakage from the Clean Development Mechanism

Rutherford (2010) - Climate linked tariffs - Practical Issues

Singleton (1997), The World Textile Industry, first edition, Routledge, New York

Smale et al. (2006), The impact of CO_2

emissions trading on firm profits and market prices. Climate Policy 6(1), 31–48

TNO (2009) - Greenhouse gas efficiency of industrial activities in EU and non-EU

UN (2003), "Energy Subsidies: Lessons Learned in Assessing their Impact and Designing Policy Reform", UNEP/ETB/2003/1

University of Iceland (2009) - The effect of power-intensive industrial developments on the Icelandic economy

Walker (2006), Concrete Evidence? An Empirical Approach to Quantify the Impact of EU Emissions Trading on Cement Industry Competitiveness. School of Geography, Planning and Environmental Policy, University College Dublin. Working Paper

Warwick and Wilcoxen (2008) - Building On Kyoto: Towards A Realistic Global Climate Agreement. CAMA Working Papers 2008-13, Australian National University, Centre for Applied Macroeconomic Analysis

WTO (2007) – Speech by Pascal Lamy, 9/12 2007

WTO (2011) staff working paper, The interface between the Trade and Climate Change Regimes: scoping the issue

Sammanfattning

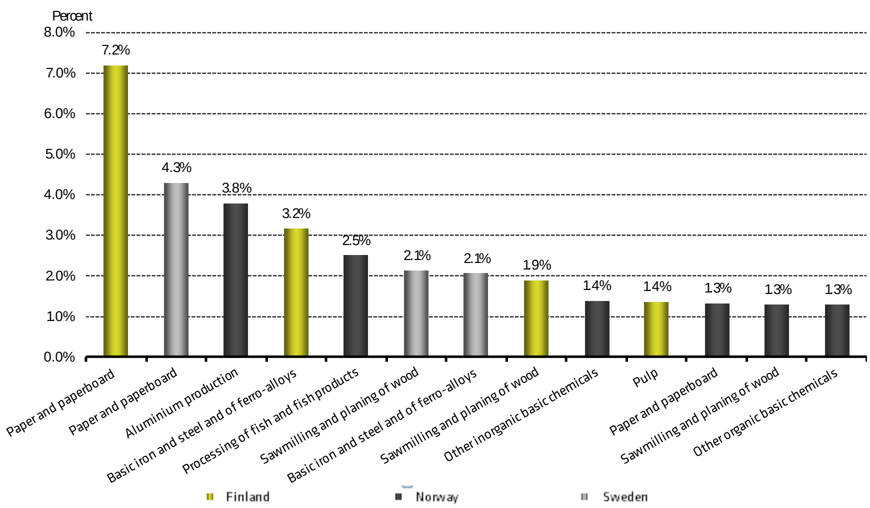
Prissättning av koldioxidutsläpp anses vara ett mycket effektivt verktyg för att reducera utsläpp och uppnå klimatpolitiska målsättningar. Genom att öka kostnaden för koldioxidutsläpp ges användare och producenter av fossila bränslen incitament att minska sin förbrukning och utveckla produkter och processer som medför låga koldioxidutsläpp.

Ett problem med prissättning av koldioxid är dock att det kan leda till kolläckage. Kolläckage innebär att koldioxidutsläppen utanför den region som prisätter utsläpp ökar. På grund av relativt höga energipriser tappar företagen inom regionen i konkurrenskraft och kan därmed tvingas lägga ner produktionen eller flytta ut den utanför regionens gränser. Konsekvensen blir att utsläppen flyttas från en plats till en annan. Mängden kolläckage uttrycks som ökningen av koldioxidutsläpp utanför regionen i procent av minskningen inom regionen. Ett kolläckage på 100 procent innebär således att prissättningspolicyn är meningslös eftersom minskade utsläpp inom regionen motsvaras av en lika stor utsläppsökning utanför regionen.

I denna rapport identifieras de 25 nordiska branscher där risken för att prissättning av koldioxidutsläpp leder till kolläckage är som störst. I arbetet med att identifiera dessa har branscherna granskats utifrån flera olika faktorer som antingen ökar eller minskar risken för kolläckage. Exempel på faktorer som ökar risken är intensiv energiförbrukning, hög energieffektivitet relativt till konkurrenter utanför regionen, och/eller förekommande av processer inom produktionen som enkelt kan brytas ut och flyttas till andra länder. Intensiv energiförbrukning och möjligheten att bryta ut processer ur produktionen ökar läckagerisken på grund av att de sätter press på utflyttning av produktion. Energi effektivitet å andra sidan ökar läckarrisken genom att utsläppen per enhet ökar om produktionen flyas utomlands. Ett klassiskt exempel på en flyttbar process finns att hämta inom cementproduktionen, där den energiintensiva produktionen av klinkers enkelt kan separeras från övrig produktion och flyttas utomlands. Faktorer som verkar i den andra riktningen (sådana som minskar risken för kolläckage) karakteriseras av att de i viss mån ”skyddar” den energiintensiva industrin från konkurrens med länder som har lägre energikostnader. Exempel på sådana faktorer är höga transportkostnader, hög grad av produktdifferentiering, begränsade möjligheter till förflyttning av produktion och politiskt relaterade handelshinder (tullar, valutarisker). Läckageprocessen kan även bromsas om produktionen är kapitalintensiv, eftersom producenterna då har en stor befintlig produktionskapacitet som kommer att användas till dess att den är förbrukad.

De nordiska industrier som bedöms vara i riskzonen för kolläckage både på kort och lång sikt finns framförallt inom sektorer med anknytning till pappers- och massaindustrin (papper och papp, sågverk och massa), järn- och stålindustrin, aluminiumindustrin, fiskerinäringen och kemikalietillverkning. Dessa riskindustrier står för mellan 1.6 procent och 14.6 procent av mervärdet i de nordiska länderna, med Danmark i botten och Finland i toppen. Sammanlagt står de för 10.2 procent av det nordiska mervärdet. De riskindustrier som är av störst ekonomisk betydelse är pappersindustrin, järn-, aluminium- och stålproduktionen.

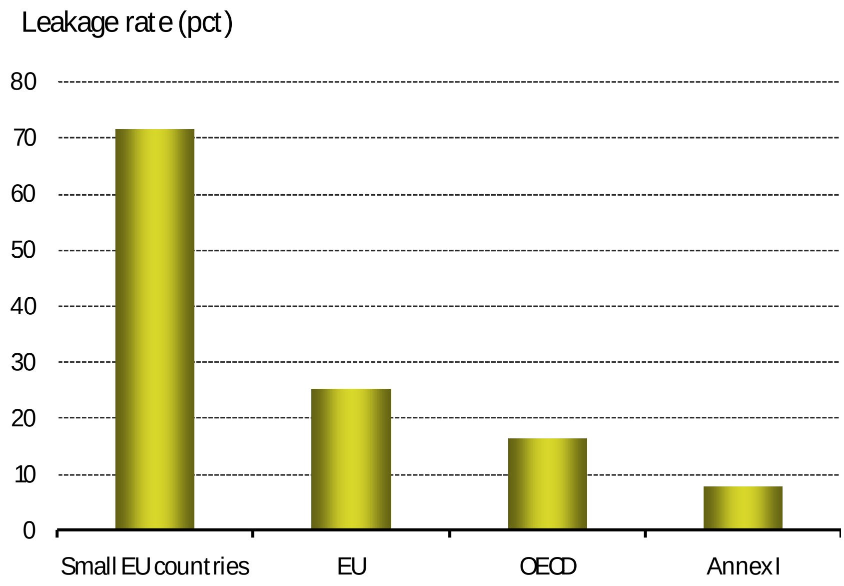
Figur: Andel av mervärdet för läckage industrier, 2007



Källa: Se figur 9 i rapporten

Det finns en stor mängd studier som behandlar problematiken med kolläckage. Uppskattningarna av kolläckagens omfattning varierar dock kraftigt. De varierande resultaten kan till stor del förklaras av studiernas olika utgångspunkter. Studier som undersöker koldioxidpolitik i mycket små regioner finner ofta högre läckagekvoter än studier som ser på större regioner. En annan orsak till de varierande resultaten är också de stora skillnaderna i studiernas metodologiska ansatser. I vår studie kommer vi att belysa denna problematik genom en genomgång av olika studiers resultat.

Figur: Koldioxidläckage beroende på regionens storlek



Källa: Se figur 10 i rapporten

Vår grundläggande slutsats är att läckagens storlek tenderar att underskattas i ett stort antal studier, framförallt på lång sikt. I många studier förbises det faktum att industrier med störst läckagerisk producerar relativt homogena produkter såsom stål, aluminium, papper och massa (vilket också är fallet i de nordiska länderna). Dessa varor säljs sedan på en global marknad till kunder över hela världen vilket innebär att prisskillnaderna är begränsade på lång sikt. Detta innebär att mycket små prisskillnader mellan de nordiska länderna och regioner utanför medför att stora delar av efterfrågan flyttas utomlands med konsekvensen att produktionen reduceras dramatiskt. Problemet blir störst på lång sikt då befintliga produktionsanläggningar är förbrukade. Studier som tar hänsyn till denna typ av långsiktiga effekter och som beaktar varornas karaktäristika finner läckagekvoter upp emot 100 procent och ännu högre för industrierna med hög läckagerisk.

I denna studie har vi inkluderat några illustrativa resultat från vår egen modell, med syftet att belysa och förklara de effekter som är förknippade med kolläckage. Utifrån dessa resultat uppskattar vi att läckagekvoter för riskindustrierna närmar sig 100 procent på kort sikt och överstiger 100 procent på lång sikt. Dessa resultat implicerar att en prissättningspolitik där koldioxidutsläpp blir väsentligt dyrare i de nordiska länderna än i övriga länder faktiskt inte kommer bidra till att reducera mängden utsläpp globalt sett, utan istället bara flytta produktionen.

Energimarknadernas funktion är av stort intresse för den nordiska diskussionen om kolläckage. Industrier som är i riskzonen för kolläckage i Norden tenderar att ta emot merparten av sin elektricitet från elnäten, medan riskföretag i andra EU länder i större utsträckning producerar sin energi själva. I förhållande till andra EU länder använder sig nordiska företag av en energimix med låga koldioxidutsläpp (vattenkraft, vindkraft, kärnkraft). Dessutom är elproducenter i nordiska länder mycket effektiva vad gäller omvandling av kol och gas till elektricitet. Detta får till följd att varje enhet energiintensiv produktion som flyttas från Norden till andra delar av EU eller andra delar av världen troligtvis kommer att åtföljas av en nettoökning av koldioxidutsläpp.

En sådan effekt skulle enbart delvis motverkas av en ökad export av överflödig "ren" elektricitet. Detta beror på flera orsaker. Den existerande infrastrukturen kan inte facilitera en stor exportökning. Dessutom har konkurrenterna till de nordiska företagen, i nyckelindustrier såsom stålindustrin och pappersindustrin, sin produktion placerad utanför EU, vilket gör att de inte får del av marginalnyttan från överskott av grön el i norden. Ett ytterligare problem har att göra med systemet för handel med utsläppsrättigheter. Eftersom mängden av utsläppsrättigheter är fastställt till ett specifikt antal sjunker priset när efterfrågan från koldioxidläckage utsatta industrier går ner. Nettoeffekten av en prissänkning blir därmed en ökad efterfrågan och högre utsläpp från industrier vars produktion inte riskerar att skapa koldioxidläckage.

På grund av detta rekommenderar vi att de nordiska länderna tar problemet med kolläckage på allvar, både på nationell nivå och inom ramen för EU:s politiska diskussioner. I kapitel 4 utvärderar vi ett antal alternativ för hantering av läckageproblematiken både utifrån ett EU perspektiv och utifrån ett globalt perspektiv. Alternativen diskuteras från ett teoretiskt och ett praktiskt perspektiv.

Vidare belyser vi två av de områden där ett gemensamt nordiskt perspektiv skulle vara motiverat:

För det första skulle de nordiska länderna gynnas av et gemensam fokus på energiintensiva industrier. Debatten inom EU har huvudsakligen fokuserat på att erbjuda gratis utsläppsrättigheter till de energiintensiva företag som konkurrerar internationellt. Problemet är dock att det enbart är företag med egen energiproduktion som tjänar på att få dessa utsläppsrättigheter, inte företag som påverkas av utsläppspriser till följd av att de använder energi från näten. Även om detta beslut kan vara svårt att förändra just nu bör de nordiska länderna se över ramverket för det statstöd som kompenserar användare av energiintensiv elektricitet. Användningen av denna åtgärd håller just nu på att utvidgas. I översynen bör man granska huruvida politiken skapar den rätta balansen mellan användande av olika typer av energi. Det är även viktigt att säkerställa att industrier varken överkompenseras eller underkompenseras. Eftersom kompensationen till konsumenter av elektricitet kommer att ske genom nationella åtgärder och då likheterna inom de nordiska riskindustrierna är många, motiverar detta att de nordiska länderna arbetar gemensamt för att garantera en enhetlig behandling utifrån EU-regleringen. Detta är viktigt för att undvika snedvridning mellan företag i Norden.

För det andra skulle de nordiska länderna även kunna gynnas av gemensamma intressen även i en bredare global klimatpolitisk kontext. De nordiska länderna deltar alla i hög grad i den globala handeln och har alla en tradition av att stötta öppna marknader och handelsliberalisering. Några av de åtgärder som just nu föreslås för att komma tillrätta med läckageproblematiken är importtullar på produkter från regioner med svag klimatpolitik. Denna typ av åtgärder kan tyckas väl riktade för att komma tillrätta med problemen, men de kan vara mycket svåra att använda i praktiken. Dessutom rimmar de illa med den politik som förs för att främja en öppen marknad. Vi föreslår istället andra möjliga åtgärder som är mer framgångsrika i att sprida klimatpolitik på en global nivå, exempelvis utvidgande av handeln med utsläppsrätter till fler länder, eller andra typer av bilaterala överrenskommelser som behandlar problematiken med koldioxidläckage.

Appendices

Appendix A: The Carbon Leakage model

This section is concerned with a technical description of the applied carbon leakage model, a discussion of the intuition of the model, and a discussion of how specific parameter assumptions affect the resulting carbon leakage ratio.

The Copenhagen Economics Carbon Leakage model (CECLM) is a simulation model specifically designed for evaluating carbon leakage. The theoretical framework is based on Gerlagh & Kuik (2007). It is a two region model describing demand and supply of an energy intensive good and for demand of carbon-energy used as input in production and the supply thereof. The two regions are connected only by a fully integrated carbon-energy market characterised by a world price for carbon-energy. The market for energy-intensive goods are assumed to be disjoint, such that there is no effect of an increase in the product price in one region on the demand of the product from the other region. In the CECLM the theoretical framework is extended to allow for direct substitution between products, following the Armington assumption of product differentiation. As a second extension, the CECLM is set up as a multi sector model, to allow for a world market for any number of individual energy-intensive goods.

Mathematical description

The model is based on n different industries denoted by $i=1,\ldots,n$. There are two different regions denoted by $l=Nordic,EU$, the Nordic countries, defined as consisting of Denmark, Sweden, Norway, and Finland, and the rest of EU27.

Each industry (i) of each region (l) produces a unique commodity. p_{il} denotes the change in the logarithm of commodity i in region l, while q_{il} is the corresponding change in the logarithm of output. Constant elasticity of demand is assumed, ε_{il}, such that demand will be given by

$$q_{il} = -\varepsilon_i p_{il} + \varepsilon_i \sigma_i \frac{\theta_{il}}{1-\theta_{il}} p_{i,-l}$$

Compared to the model of Gerlagh & Kuik, the second term of the demand equation is an extension, by which interaction between product markets in the two regions is introduced. σ_i is a share parameter, which determines to what extend a change in demand of products from region

l, say the Nordic countries, takes place through direct substitution with similar products from the EU. Finally, the cross price elasticity,

$$\varepsilon_i \sigma_i \frac{\theta_{il}}{1-\theta_{il}}$$

depend on the relative market share of region i in the world market for industry i products, denoted θ_{il}. Supply of energy intensive products is assumed to be competitive. Further, capital and labour costs per unit of production are assumed to be fixed, such that only changes in the world-market price for carbon-energy, p^{carbon}, and the regional carbon tax, τ_l, affects the product price. α_{il} is the cost-share of carbon-energy, such that the relation between the product price and the costs of carbon-energy is as follows:

$$p_{il} = \alpha_{il}(p_{carbon} + \tau_l)$$

The demand for carbon-energy of region l is defined as the sum of demand of all energy intensive industries i. Following the general convention, E_l is to be interpreted as percentages change in the demand for carbon-energy. Therefore demand for energy of each industry is weighted by their share of total emissions, λ_{il}. The demand for carbon-energy of each industry varies proportionally by production, but is also affected by the ability of firms to substitute towards other sources of input. The elasticity of substitution is denoted μ_i, such that

$$E_l = \sum_{i=1}^{n} \lambda_{il}[q_{il} + \mu_i(p_{il} - p_{carbon} - \tau_l)]$$

To close the model, a market equilibrium for carbon energy is needed. On the demand side (left), δ_l is the country share of total CO^2 emissions, by which the change in demand in each region is weighted. The change in the supply of carbon-energy depends positively of the price by an elasticity of supply, φ, such that

$$\delta_{EU}E_{EU} + \delta_{Nordic}E_{Nordic} = \varphi p_{carbon}$$

Finally carbon leakage is defined as the increase in carbon-energy in Europe relative to abatements in the Nordic countries, in response to an increase in the input tax on carbon energy τ_{Nordic}:

$$Carbon\ Leakage = \frac{\delta_{EU}E_{EU}}{\delta_{Nordic}E_{Nordic}}$$

Calibration and model intuition

In the study by Gerlagh and Kuik (2007), we find a survey of values for the behavioural parameters. We choose reasonable mean values in the model. However, we do choose to set price- and cross-price elasticities relatively high compared to other studies, to reflect the homogeneity of most of the products in question and the long term perspective. These are the chosen parameter values:

$\varepsilon_i = 4.5$
$\sigma_i = 0.9$
$\varphi = 0.3$

For the present study CECLM has been calibrated to simulate a leakage ratio for the total of those sectors that were found at the highest risk of carbon leakage in Chapter 2, the sectors listed in Table 3 and Table 5 that is.

When a tax on carbon is introduced to the industries of the Nordic countries, they are faced with the choice of incurring higher costs, and hence loose market shares, or to substitute towards other types of inputs. For example a substitution towards some type of renewable energy.

The ability to substitute towards non-carbon inputs is described by the input factor elasticity, μ_i, which in this study is assumed to take on a value of 0.1. This basically implies that firms will find it optimal to emit 1 per cent less CO_2 at any given level of production if the price of CO_2 goes up by 10 per cent.

The carbon cost share, α_{il}, of the Nordic industries is on average 6 per cent, and for the remaining EU it is 10 per cent[56]. Therefore a 10 per cent increase in the price of CO_2 will lead to an increase in the product price of 0.6 per cent.

The elasticity of demand is chosen as $\varepsilon = 4.5$, such than an increase in the product price of 0.6 as above, will lead to a 2.7 per cent drop in demand of energy intensive products produced in the Nordic countries. The total of the two first order effects are abatements of 3.7 per cent per 10 per cent increase in the carbon price differential.

It is assumed that a fixed share of 90 per cent, $\sigma = 0.9$, of the income that consumers do not spend on the now more expensive Nordic energy intensive product instead leads to increased spending on comparable goods from the remaining EU. The underlying assumption is that similar products produced abroad are on average a much better substitute than any non-energy intensive product.

The first order effect of substitution is further exaggerated by the differences in CO_2 intensities, hence λ_{il} and δ_l. Cf. Table 10 (long run net

---

[56] Apart from the CO_2 intensity these numbers are based on an assumed carbon energy price of 30 EUR per ton. Copenhagen Economics (2011)

list), the CO_2 intensity of EU industries is about 75 per cent higher than that of Nordic industries. Therefore, the part of abatements induced by a drop in demand is counteracted not by 90, but by 150 per cent.

The last of the behavioural parameters of the model is the elasticity of carbon energy supply, φ. It is worth noting that supply must equal demand, also in the market for carbon energy. Imagine that carbon supply is completely inelastic (φ=0). Then, no matter what policy is adopted, the total level of CO_2 emissions will remain unchanged, and hence the carbon leakage rate will be 100. The parameter is assumed to take on a value of 0.3. In other words, it takes a 1 per cent drop in the carbon price to induce a 0.3 per cent drop in the supply of carbon-energy. This rather low value is the main reason why the simulated leakage rate is not higher than is the case (102 %), despite of the first order effects as described above.

The increased demand for EU products leads to a net increase in the demand for carbon-energy, and hence an increase in the price thereof. This puts an upward pressure on the price of EU products, which serves to counteract the initial shift in demand towards EU products.

The final parameters are the market shares, θ_{il}. These are based on the same data for gross value added as used throughout the study. On average, the Nordic industries included have a market share of just 10.2 per cent. The low size of the Nordic region, relative to the whole of Europe, work to push the leakage rate up, since the smaller the region that introduces a policy to reduce emissions is, the higher the rate of leakage will be.

To explain why, imagine a world wide tax on carbon ($\theta = 1$). In that case there will be no opportunities for substitution towards products from non abating countries, the downward pressure on the gross price of carbon energy will be maximised, and hence carbon leakage will be 0.

The Carbon leakage ratio explained

The result of the calibration is an estimated leakage ratio of 102 per cent.

The key factors behind this result are, as discussed above.

First order effects:

- The assumption of a high cross price elasticity leads to a 90 per cent substitution towards foreign energy intensive goods
- The relatively low CO_2 efficiencies of EU industries makes the increased demand turn into a substantial increase in EU demand for carbon energy

Second order effects:

- Because of the low market share of Nordic industries the increase in EU demand dominates the Nordic abatements, such that there is a substantial net increase in the demand for carbon energy
- The assumption of a low supply elasticity of carbon energy and the increase in the carbon price which follows from this, works in the opposite direction of the effects described above, and hence depresses the leakage ratio towards a value of close to 100

The simulated carbon leakage ratio is not meant to simulate the result of any particular policy experiment, but rather as an illustration of the determinants of carbon leakage from a Nordic perspective. We have opted for a simple and intuitive modelling approach, in order to also highlight the effects of the exact behavioural assumptions made, as discussed in this appendix.

Appendix B: Value added of leakage exposed industries

Table 12: Share of total value added of the net list industries

NACE	Industry	Denmark	Finland	Sweden	Norway	Nordic average
2112	Manufacture of paper and paperboard	0.2%	7.2%	4.3%	1.3%	**3.7%**
271	Manufacture of basic iron and steel and of ferro-alloys	0.0%	3.2%	2.1%	0.9%	**1.7%**
201	Sawmilling and planing of wood; impregnation of wood	0.2%	1.9%	2.1%	1.3%	**1.6%**
2742	Aluminium production	0.3%	0.0%	0.3%	3.8%	**0.8%**
2111	Manufacture of pulp	0.0%	1.4%	1.1%	0.3%	**0.8%**
152	Processing and preserving of fish and fish products	0.9%	0.1%	0.1%	2.5%	**0.7%**
2413	Manufacture of other inorganic basic chemicals	0.0%	0.5%	0.3%	1.4%	**0.5%**
2414	Manufacture of other organic basic chemicals	0.0%	0.3%	0.4%	1.3%	**0.5%**
2416	Manufacture of plastics in primary forms	0.1%	0.6%	0.6%	0.4%	**0.4%**
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	0.2%	0.9%	0.2%	0.3%	**0.4%**
1571	Manufacture of prepared feeds for farm animals	0.3%	0.2%	0.0%	0.9%	**0.3%**
275	Casting of metals	0.2%	0.3%	0.2%	0.3%	**0.3%**
154	Manufacture of vegetable and animal oils and fats	0.3%	0.0%	0.2%	0.6%	**0.2%**
2744	Copper production	0.0%	0.4%	0.3%	0.0%	**0.2%**
2122	Manufacture of household and sanitary goods and of toilet requisites	0.0%	0.1%	0.5%	0.0%	**0.2%**
2441	Manufacture of basic pharmaceutical products	0.2%	0.0%	0.0%	1.1%	**0.2%**
265	Manufacture of cement, lime and plaster	0.0%	0.2%	0.1%	0.2%	**0.1%**
2745	Other non-ferrous metal production	0.0%	0.3%	0.1%	0.2%	**0.1%**
1531	Processing and preserving of potatoes	0.0%	0.1%	0.1%	0.2%	**0.1%**
2415	Manufacture of fertilizers and nitrogen compounds	0.0%	0.2%	0.0%	0.3%	**0.1%**
2412	Manufacture of dyes and pigments	0.1%	0.2%	0.0%	0.1%	**0.1%**
172	Textile weaving	0.0%	0.0%	0.1%	0.1%	**0.0%**
1583	Manufacture of sugar	0.0%	0.1%	0.0%	0.0%	**0.0%**
264	Manufacture of bricks, tiles and construction products, in baked clay	0.1%	0.0%	0.0%	0.0%	**0.0%**
1562	Manufacture of starches and starch products	0.1%	0.0%	0.0%	0.0%	**0.0%**

Note: The Nordic average is a weighted average weighted by each country's value added.

Source: Copenhagen Economics based on Eurostat data.

Content

Preface

Increasing the price of emitting CO_2 into the atmosphere is a forceful instrument. At the EU level, this is pursued through the common Emission Trading Scheme (ETS). At the national level, the ETS price is complemented by other implicit prices on CO_2 such as taxes on energy consumption and levies on electricity to finance renewable energy investments.

Such climate related policies are designed to reduce emissions by increasing the cost of energy intensive products and thereby lowering the demand for energy intensive products, and spurring more energy efficient innovations. However, in a globalised world with decreasing transport costs, foreign competitors from regions with less strict climate policies stand ready to serve the market with cheaper products. This means that domestic production, and the corresponding CO_2 emissions, is of the risk of moving abroad as a response to higher cost of energy, either through decisions to moving production facilities abroad or simply by being outmatched and forced to close production. The phenomenon that domestic CO_2 reductions may be offset by increased CO_2 emissions abroad is known as *carbon leakage*.

The Nordic Council of Ministers have commissioned Copenhagen Economics to assess the Nordic industries that are the most exposed to carbon leakage, and evaluate the characteristics of different instruments that could deal with the risk of carbon leakage. The analysis finds that leakage risks are very tangible and should be taken seriously. A specific area of interest to Nordic policy makers should be how to compensate energy intensive electricity consumers exposed to leakage risks. The analysis has been carried out during the period August 2011 – December 2011. The authors have been:

- Partner, Sigurd Næss-Schmidt, Copenhagen Economics
- Economist, Martin Bo Hansen, Copenhagen Economics
- Economist, Jens Sand Kirk, Copenhagen Economics

Copenhagen, 2 December 2011

Halldór Ásgrímsson
Secretary General
Nordic Council of Ministers

Summary

Setting a price on CO_2 is generally considered a highly effective tool to reduce carbon emissions and achieve abatement targets in climate policies. By raising the cost of emitting CO_2, it provides incentives for user and producers of fossil fuels to reduce consumption and develop low carbon products and processes.

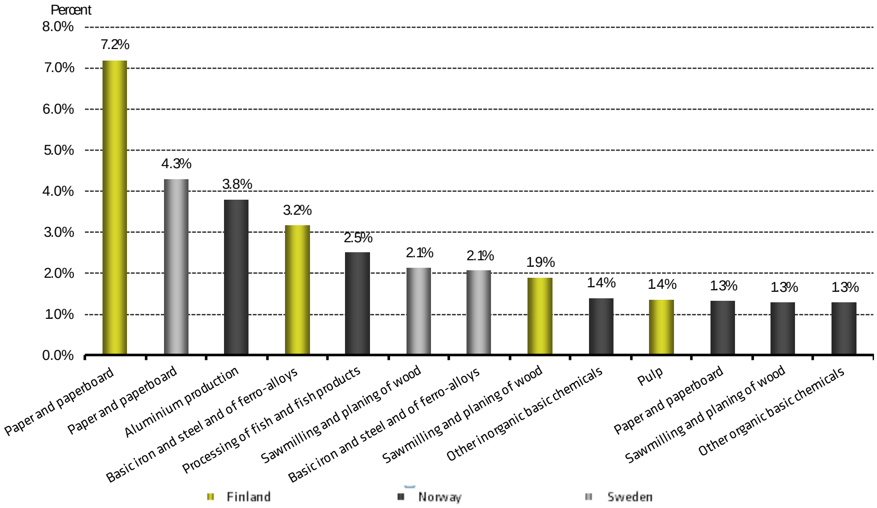
However, putting a price on CO_2 is also recognised as leading to carbon leakage: i.e. carbon emissions outside the region pursuing carbon policies may increase as firms inside the region lose competiveness due to higher energy prices. In this context, carbon leakage expresses how much carbon emissions increase outside the carbon policy region as a per cent of the abatement that is achieved within the region. A leakage per cent of 100 implies that the specific carbon policy regime is completely futile, since every unit of domestic abatement is followed by an equal rise outside the region.

This report identifies the 25 most leakage exposed industries in the Nordic area. The identification of these industries is based upon a number of leakage drivers and brakes. Drivers are characteristics that lead to carbon leakage. Such drivers are intensive energy consumption, high energy efficiency relative to competitors outside the region, and/or the existence of processes within the industry that are easy to split up and produce in other countries. While intensive energy consumption and the possibility for splitting up processes will drive leakage by increasing pressure to produce abroad, high energy efficiency within the region will drive carbon leakage through the fact that emissions will increase pr. unit of production if production is moved abroad. A classical example is the energy intensive production of clinkers related to cement production. Brakes are characteristics that somewhat "protects" an energy intensive industry from competition from countries with lower energy costs; at least temporarily. These brakes are high transportation costs per unit of value, high degree of product differentiation, limited transportability, and more policy related trade barriers (tariffs, exchange rate risks). In addition, a high level of capital intensity may imply that a producer has a substantial existing production capacity which will be used until it is run down: this will slow down the leakage process.

It is primarily sectors related to the paper and pulp industry (paper and paperboard, sawmilling, and pulp), iron and steel, aluminium, processing of fish, and manufacture of chemicals that are determined to be at risk of carbon leakage in the Nordic countries. These key leakage exposed industries account for between 1.6 per cent and 14.6 per cent of

value added in the Nordic countries, with Denmark at the lowest end and Finland at the top end. Out of total Nordic value added, these industries account for 10.2 per cent. The economically most important leakage exposed industries are paper and paperboard, aluminium and iron and steel production.

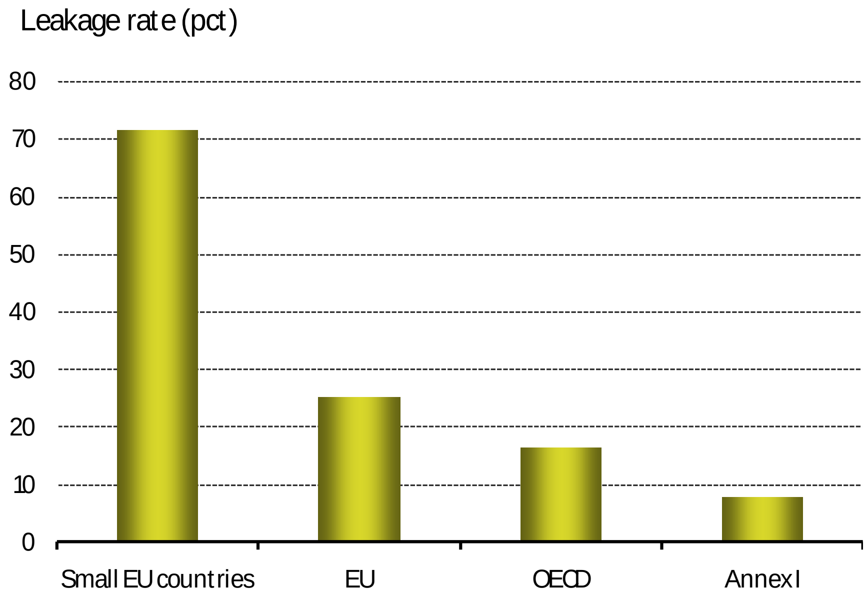
Figure: Shares of value added for key leakage industries, 2007



Source: See figure 9 in the report.

There is a large variation in estimates of carbon leakage in the literature on the issue. This partly reflects underlying fundamental differences, e.g. studies that look at carbon policies in very small regions typically find higher leakage ratios than studies looking at larger regions. But the variation in leakage estimates is also a reflection of very different methodological approaches. We conduct a review of these estimates in our study.

Figure: Leakage rates depending on region size



Source: See figure 10 in the report.

One basic conclusion we draw is that a large number of studies tend to underestimate the size of leakage, particularly seen from a long term perspective. Essentially, they tend to overlook the ramifications of the basic fact that most leakage-exposed sectors produce quite homogenous products such as steel, aluminium, paper and pulp (as in the Nordic countries) which are traded in global markets to customers all over the world with limited long term price differences. Basically, this implies that even small price differentials with regions outside the Nordics will shift most (if not all) demand abroad, and production will be dramatically reduced, especially over the long term once existing production facilities are run down. Studies that allow for such longer term effects and recognise the "commodity-characteristic", find leakage rates approaching 100 per cent and even exceeding this.

We have included in our report some illustrative model results from our own model, mainly to illuminate and explain the effects associated with carbon leakage. We suggest that leakage rates for the key Nordic industries at risk of leakage approach 100 per cent in the short run and even exceed 100 per cent in the long run. This implies that imposing a substantial carbon price in the Nordics will essentially not reduce global emissions but instead lead to production displacement.

The functioning of power markets are of particular interest in a Nordic carbon leakage discussion. Leakage exposed industries in the Nordics tend to get most of the energy as electricity from the power grid while corresponding firms in other EU countries tend to produce more of their own energy. This also implies that Nordic electricity consist of a very low-carbon energy mix (hydro, wind, atomic power) relative to their counterparts in other EU countries. Moreover, power generators in Nordic countries are highly efficient in converting coal and gas to electricity. These two factors in conjunction imply that every unit of energy intensive production moved from the Nordic area to other parts of EU or other parts of the world are likely to be followed by a net increase in carbon emissions (increased carbon intensity per unit of production globally.).

Such effects will only partly be offset by increasing the exports of redundant "clean" electricity for several reasons. Existing infrastructure cannot facilitate such a massive increase in exports. Moreover, competitors to Nordic firms in key industries such as steel, paper and pulp production are in any case placed outside the EU, so they are not the marginal beneficiaries of surplus green electricity from the Nordic area. Finally, with a fixed amount of ETS allowances and a lower demand for allowances from leakage exposed industries, the allowance price will fall. Hence, the net effect of reduced electricity demand from leakage exposed industries will be an increase in demand - and hence higher level of emission - from non-leakage exposed industries, due to the lower electricity price within EU and the shift of carbon intensive production towards non-EU countries.

Hence, we recommend that the Nordic countries nationally and in the context of EU political discussions take carbon leakage seriously. In chapter 4, we examine a number of the present options to deal with carbon leakage both in EU and in a global context, both from a theoretical and from a practical perspective.

We have also identified at least two areas where a more common Nordic perspective may be warranted:

First, a special focus on energy intensive industries using electricity. Most of the debate within the EU has focused on providing free allowances to energy intensive firms in international competition. However, it is only firms with own energy production that can benefit from allowances, not firms exposed to carbon pricing through their use of electricity from the grid. This is a decision that may be difficult to change now. However, the Nordic countries should look carefully into the State aid framework for compensating energy intensive electricity users, currently in the process of being reviewed and expanded by the Commission, to see if it provides the proper balance between the use of different types of energy, and neither over nor under compensates industries. Moreover, as the compensation to electricity consumers is to take place by national measures, and as there are a lot of similarities in terms of leakage exposed industries within the Nordic countries, the argument for ensuring consistent treatment in EU regulation in order to avoid very strong distortions between firms in the Nordic region weighs even heavier.

Second, in a wider global climate policy context the Nordic countries may also share some common interests. All countries are heavily engaged in global trade and have a tradition for and an interest in supporting open markets and trade liberalisation. Some of the measures currently on the table to deal with carbon leakage, such as import tariffs on products from regions with weak climate policies, seem in theory well targeted to deal with carbon leakage but are very difficult to implement in practice. Moreover, such measures may be difficult to reconcile with an open market mindset. We suggest taking other possible routes that have more success in disseminating climate policies at the global level such as expanding emission trading schemes to other countries or engaging in other types of bilateral agreements addressing carbon leakage.

1. Drivers and size of carbon leakage

1.1 What is carbon leakage?

In order to reduce carbon emissions, the most efficient instrument is to increase the price on carbon. A price on carbon will influence two behavioural channels: 1) consumers and industries change their behaviour to consume less carbon e.g. by buying fewer cars and/or driving fewer kilometres, and 2) consumers and industries substitute their consumption towards goods that use carbon more efficiently e.g. smaller and/or more fuel efficient cars. These effects are illustrated in the lower panel in Figure 1.

Carbon abatement policies such as increasing the price on carbon will reduce emissions *inside* the region adopting the policy. However, a part of this reduction may be offset by an increase in emissions *outside* the region. This effect is known as *carbon leakage*. Carbon leakage is a concept that depicts the degree to which carbon emission reductions in a region with carbon abatement policies are offset by increased emissions outside the region.[1] If, for example, the EU implements policies that reduce emissions by 100 units and emissions subsequently increase by 70 units outside EU, then the carbon leakage rate is 70 per cent.

Carbon leakage is spurred not just by an increased price on carbon. Most countries do not seek to reduce CO_2 emissions purely by putting a price on CO_2, as is the case with e.g. the EU ETS. Instead, climate policy is conducted by increasing renewable energy production capacity, increasing energy taxes, and adopting certain climate related standards for certain products, such as e.g. the efficiency of a car engine. Such policies all have a cost (e.g. higher electricity bills and higher product prices) which can be interpreted as the implicit cost of CO_2 reductions (or just the implicit price of carbon). What matters for carbon leakage is not the price of carbon per se (the ETS price in Europe), but the implicit cost of CO_2 reductions, which is the sum of the above elements.

Carbon leakage may take place through two channels:

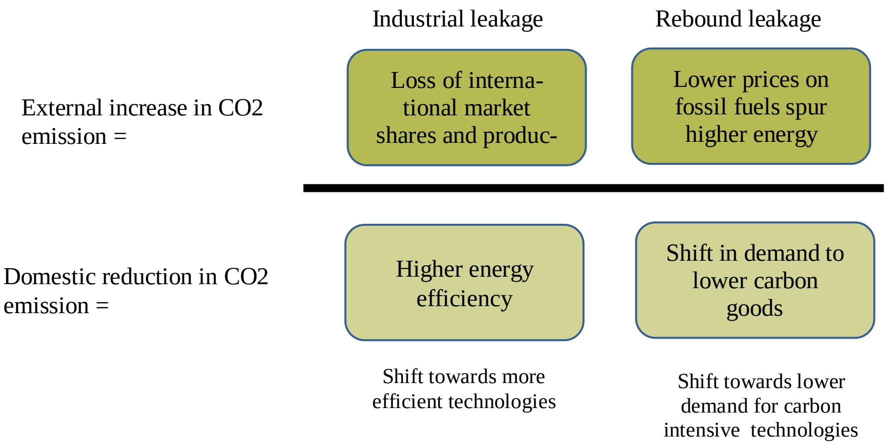
1. Domestic producers face higher production costs and will therefore lose competitiveness on the global market. Foreign competitors will

[1] See e.g. IPCC (2007).

respond by increasing production (and emissions) in order to utilise the cost differential created by the carbon tax. Moreover, domestic producers may also respond by moving production facilities abroad. This is known as *industrial (carbon) leakage*

2. By reducing energy consumption *inside* a sufficiently large region with high carbon prices this will tend to lower the global energy price. In turn this will stimulate energy demand (and emissions) *outside* the region. This is known as *rebound (carbon) leakage.* These effects are illustrated in the upper panel in Figure 1

Figure 1: Conceptual presentation of carbon leakage



Source: Copenhagen Economics inspired by IEA (2008b).

Rebound leakage is primarily of relevance when evaluating the policies of a large region. The actions of a small region, such as the Nordic region, will not have a large impact on the global energy price and the rebound channel will not be of particular importance. On the contrary, *industry leakage* is very relevant from a Nordic perspective, since the Nordic countries are small open economies with a relatively high level of carbon (and energy) taxation. Consequently, firms are facing a high degree of foreign competition, and are likely to face difficulties withstanding further reductions in their competitiveness.

There are several examples of production facilities in a region with high production cost which have been relocated to lower cost regions through competitive pressure. Classic examples are the shipbuilding industry moving from Europe to cheap-labour regions in Asia over the past five decades[2], the textile industry (one of the main drivers in the European industrial revolution) moving to South East Asia and Central

[2] Hoffmann (2004).

America[3], and mining and heavy industry moving to Eastern Europe and further East in the 1990s to take advantage of energy subsidies[4]. The last decades have taught us that businesses are becoming ever more mobile through international trade and foreign direct investments, so similar stories are likely to take place and even at a faster rate in conjunction with decreasing costs of transports.

How firms' behaviour affect carbon leakage

In response to higher cost, there are basically four options open to a firm:

1. Pass on
2. Abate
3. Innovate
4. Relocate, scale down, or close

These options are not mutually exclusive. For example, a firm may be forced to scale down even when it is also abating or innovating.

1. *Passing on tax increases to consumers* will allow firms to maintain a certain profit margin and therefore maintain production. The less able a firm is to pass on a tax increase the more likely it will succumb to international competitive pressure. The ability to pass on tax increase depends on a variety of factors including the competitive nature of the market and product differentiation (substitutability)[5]
2. *Abatement using existing technologies* will be a way of reducing the impact on production cost from a higher (implicit) price of carbon. For example, installing a Carbon Capture and Storage technology (CCS) can reduce emissions and hence reduce the impact of the tax. Yet, the technology also comes at a cost and it will not remove the burden entirely. In particular, the cost of the emission reducing technology per unit of CO_2 displaced has to be lower than the carbon price in order to be economically relevant for the firm
3. *Innovations* have a longer and more extensive time perspective. Innovations can reduce the tax burden in the future, and moreover potentially create entirely new markets where the firm can add to its profits. However, innovations that are only profitable in high-taxed regions will not be profitable in lower-tax regions, and hence cannot be exported to such regions. This makes it difficult for firms in relatively small economies, which to a larger extent sell to markets in

[3] Singleton (1997).
[4] UN (2003).
[5] See e.g. IEA (2008b).

other regions, to recover the costs of innovation and therefore has less incentive to innovate[6]

4. *Relocating, scaling down, or closing down production* is where carbon leakage becomes relevant. Scaling down production may be the objective of domestic climate policy in order to reduce emissions; however this policy is not effective if foreign firms simply take over market shares and maintain the level of global emissions. Moreover, if the current location of the production plant was chosen inter alia to minimize transportation cost (which economic theory would predict), it also implies that relocation leads to additional transportation, additional emissions, and efficiency losses

The firms' actual choices will depend on a number of drivers and brakes, which are industry-specific. We will explain these in more detail in the next section.

1.2 Drivers and brakes of carbon leakage

In this section, we look at the most important drivers and brakes that affect the size of industrial carbon leakage.[7] As mentioned above, the size of carbon leakage is a measure of how much emissions increase outside the policy-region as a response to an increase in the (implicit) price of carbon. In the EU context, policy makers are especially concerned with specific industries' *risk of carbon leakage*. An industry may be more or less at risk of carbon leakage depending on specific structural characteristics of the products produced in the industry. In the context of the EU ETS Directive, carbon leakage is primarily assessed by a product's *energy intensity* and *trade exposure*.[8] The more energy input is used per unit output, the higher the products' risk of leakage is, and moreover the higher the competitive pressure is from abroad, the higher the risk of leakage is. We however, argue that this approach is simplified. While these two variables are indisputably important for carbon leakage, trade exposure is to a large extent driven by other underlying factors, which are more interesting to evaluate, since trade exposure in itself should not be sufficient to be deemed at risk of carbon leakage. Moreover, other variables are important in order to assess the risk of carbon leakage. To be able to properly ad-

[6] See e.g. Copenhagen Economics (2010).

[7] From here on, we focus on industrial carbon leakage and not on rebound leakage, since this is what is most relevant for the Nordic countries.

[8] These two factors determine whether or not an industry can be deemed"at the risk of carbon leakage" and thereby be eligible to special treatment. From 2013, industries at risk will continue to receive 100 per cent free ETS allowances instead of the gradual reduction to 30 per cent by 2020 applicable to other industries.

dress the risks of carbon leakage of each particular industry, we argue that the following drivers and brakes should be explored:

Drivers
- 1.2.1 Energy intensity
- 1.2.2 Ability to split and outsource the production processes
- 1.2.3 Relative energy efficiency in production and fuel mix

Brakes
- 1.2.4 Transportation costs and transportability
- 1.2.5 Capital intensity
- 1.2.6 Trade barriers and exchange rate risks
- 1.2.7 Product differentiation

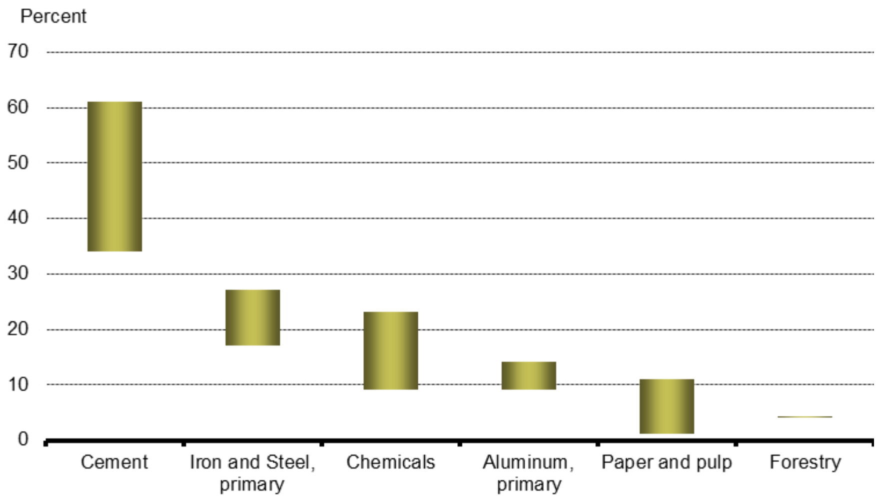
1.2.1 Energy intensity

The impact on production cost from increasing carbon costs, and the associated risk of carbon leakage, will generally (but not always) be greater in industries that use a large amount of energy. The most commonly used energy sources in the Nordic countries are electricity, fossil fuels and to a minor extent renewable energy consumed directly (not through electricity production). Increasing the implicit carbon price will affect the price of both fossil fuels and electricity (through e.g. green certificate prices, and ETS allowances prices), and therefore also the main sources of energy input. Industries that are highly energy intensive are cement, iron and steel, refined petroleum, fertilisers, chemicals, aluminium and pulp and paper.[9]

The production costs of industries such as aluminium, chemical, and iron and steel are estimated to increase by more than 10 per cent for a carbon price of €20 per ton, cf. Figure 2. The cement industry is the most vulnerable with increased production costs of up to 60 per cent.

[9] See e.g. Hourcade et al. (2007).

Figure 2: Short run impact on production costs from a carbon price of €20 per ton



Note: The studies consider a carbon price of €20 per ton. Note also that the studies only consider the direct impact on production costs and not the opportunity costs related to the relative price of renewable energy waste products cf. the discussion below. This is especially relevant for the paper and pulp industry with supply of waste materials from wood processing.

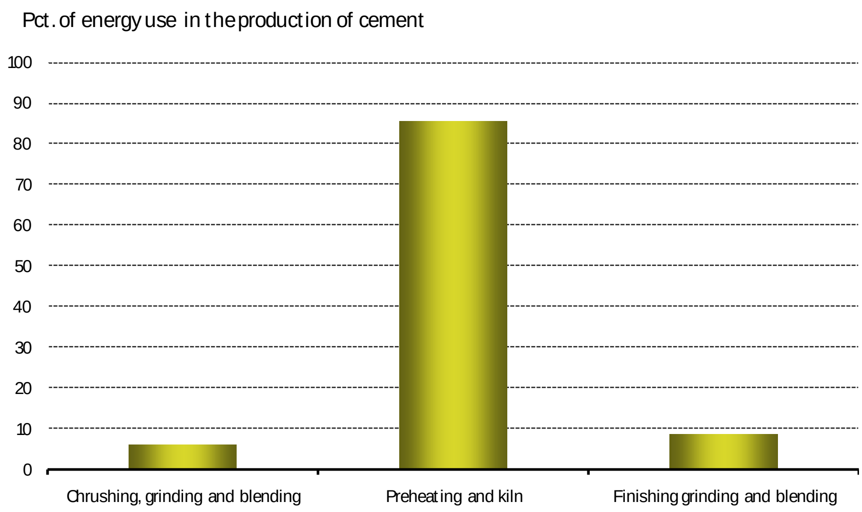
Source: Copenhagen Economics based on IEA (2005), Smale et al. (2006). McKinsey and Ecofys (2006), and Climate Strategies (2007).

Industries that use a large share of renewable energy in production will not be directly affected as much by an increase in the carbon tax, and may even benefit through a better competitive standing. Due to this, it may be relevant to also consider the *fossil fuel intensity*. However, even for industries that use a lot of renewable energy there is an opportunity cost of consuming this energy. As the price of carbon intensive energy sources increase, renewable energy becomes increasingly attractive and hence demanded more. This drives up either the direct cost of purchasing renewable energy or the opportunity cost of consuming own production of renewable energy instead of selling it on the market. Industries in the Nordic region where these arguments are relevant are related to the paper industry, where renewable energy is consumed directly due to the combustible waste products associated with processing wood.

1.2.2 Ability to split and outsource the production process

Carbon leakage may occur since the impact of an increased price of carbon on production costs can be mitigated by outsourcing the most energy intensive part of the production process to regions with lower prices on carbon. One prominent example of such splitting and outsourcing is clinkers which are used to produce cement. Producing clinkers by heating limestone in a kiln is by far the most energy intensive process of cement production, cf. Figure 3. Consequently, by relocating clinkers production to regions with low carbon prices, firms may save a substantial amount of production costs.

Figure 3: Energy use in production of cement



Source: Copenhagen Economics based on IEA (2008b).

Some industrial processes are not currently outsourced due to physical or structural limitation, while others are not outsourced since e.g. the transport costs are too high. Cement has previously been considered a product unsuitable for outsourcing, but due to a sufficiently high carbon price a substantial outsourcing of clinkers production takes place today. For example, imports of clinkers from Morocco and Egypt to Spain were substantial during the construction boom in Spain in 2003-2006.[10]

1.2.2 Relative energy efficiency in production and fuel mix

The size of carbon leakage will depend on the relative energy efficiency between firms in the region with a high carbon price and the region without. If the firms in the region with a carbon price are relatively more energy efficient than in the low-tax region, there will be an increase in total carbon emissions for each unit production that is moved from the taxed to the non-taxed region and vice-versa. This may theoretically give rise to a leakage rate above 100 per cent. A study we conducted in relation to Danish energy taxation found a carbon leakage rate of 88 per cent, inter alia

[10] Ponssard and Walker (2008)

contributed to the fact that Danish production was relatively energy efficient compared to the regions with a lower carbon price.[11]
Moreover, the fuel mix used in production in various regions will also affect the size of carbon leakage. This is especially relevant in electricity production where the fuel mix in different regions and countries vary substantially from app. 10 per cent (several Eastern European countries) to 99.9 per cent (Iceland). If production moves from a region with a high share of renewable energy to a region with a lower share, emissions will consequently increase per unit of production hence increasing carbon leakage.[12]

1.2.3 Transportation costs and transportability

Transportation costs will among others determine how competitive a geographically distant producer is. If it is very costly to bring the product to the market, there is both limited competition from abroad and a limited scope for moving production away. Products will thus be less at risk of carbon leakage when transportation costs are high. This is also equivalent to the fact that carbon leakage risks has increased in conjunction to globalisation and the structural reductions in transportation costs.

Transportation costs are closely related to product characteristics. Fresh milk is heavy and easily decomposed and therefore expensive to move. Milk powder, on the other hand, can be stored at limited costs and is much more weight-efficient to transport. A similar example holds for cement where clinkers (the input) are cheaper to transport than actual cement (the output) (see also above). Products with high storability and low weight/value ratios are therefore generally more at risk of carbon leakage as they are both relatively cheap and possible to transport.

Other factors such as health and environmental factors could also have an impact on the tradability of a product. Chlorine, for example, is a hazardous substance that makes it less suitable to transport, thus reducing the ability to substitute foreign production for domestic production and therefore reducing the risk of carbon leakage.[13]

1.2.4 Capital intensity

While the current costs of carbon taxes are relatively easy to estimate, there is much more uncertainty about long-term effects on both costs and production. Consider for example industries that are relatively capital-intensive. Since capital-intensive firms normally have undertaken

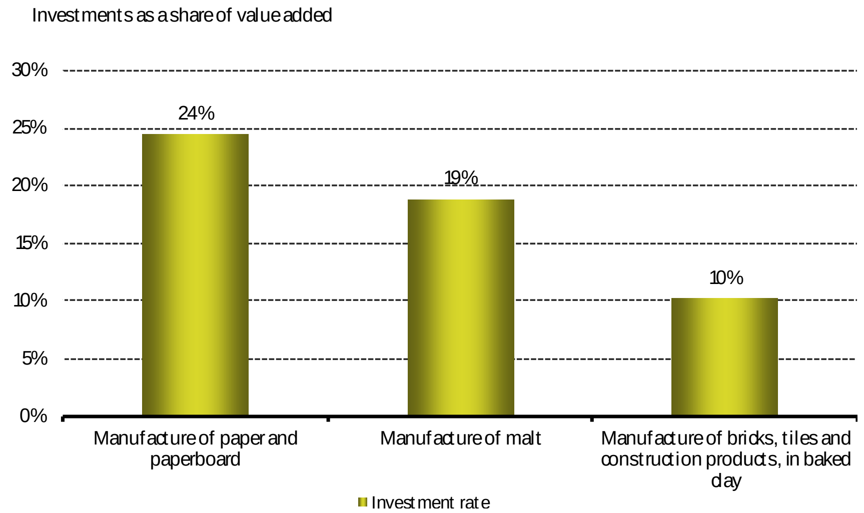
---

[11] Copenhagen Economics (2011).
[12] See e.g. TNO (2009).
[13] Congressional Research Service (2008).

significant investments up front, such firms may respond to competitive pressure by lowering prices but remaining in business until new investments are due. When the capital stock is sufficiently depreciated, firms may either find it unprofitable to undertake new investments and close production, or move production to regions with lower carbon prices.[14] In such a case, carbon leakage will be much higher in the long run than in the short run, and carbon leakage based on current observations and modelling may be underestimated.

In order to assess capital intensity, we consider industries' investment rates.[15] The capital intensity varies across industries, with e.g. manufacturing of paper and paperboard investing with a rate of 24 per cent, cf. Figure 4. This suggests that carbon leakage in industries such as the paper and paperboard industry tend to materialise in the longer run since firms will not close down production immediately due to their large capital investments. This will be discussed further in Chapter 2.

Figure 4: Capital intensity of different industries



Note: Calculated as an average of the Nordic countries where data was available.

Source: Copenhagen Economics based on Eurostat - Annual detailed enterprise statistics.

---

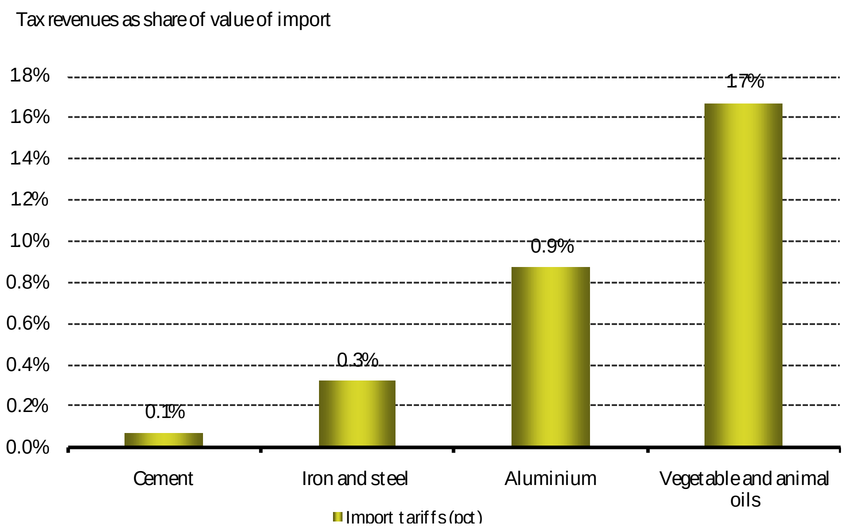
[14] Under the condition that production does not lead to economic losses. In this case the proper response is to close down production immediately.
[15] The investment rate as is a fairly good approximation for capital intensity, since a large capital stock requires a relatively high investment rate to maintain the capital stock level. This measure does not however, capture that there may be different capital depreciation rates between industries, and is therefore not a perfect approximation.

1.2.5 Trade barriers and exchange rate risks

A reverse driver, i.e. a brake, of carbon leakage is the existence of trade barriers. If a region has set up trade barriers e.g. in the form of import tariffs or non-tariff barriers, foreign produced goods will be more expensive and hence less attractive in the domestic market. By increasing the price of goods from low carbon price regions, the price differential between regions with ambitious and less ambitious climate policies respectively is reduced. Consequently, this reduces the risk of carbon leakage.

EU import tariffs vary largely across products. While tariffs on vegetable and animal oils generate 1.7 per cent tax revenue per value of import, tariffs on cement only generate 0.1 per cent revenue per value of import, cf. Figure 5. This indicates that products such as vegetable oils are less at risk of carbon leakage than they would be if import tariffs were lower.

Figure 5: Import tariffs on different products



Note: Import tariffs are calculated at an EU aggregate level. Specific Norwegian import tariffs are not included here.

Source: Copenhagen Economics based on WITS database.

This suggests that intra-EU leakage rates, *for a given energy-price differential*, may be higher than e.g. between EU and third countries, since there are no import tariffs between EU Member States. In the absence of any trade barriers, even small price differentials e.g. between the Nordic countries and the rest of EU may give rise to intra-EU leakage.

While probably less important, the existence of exchange rate risks may also be a (reverse) driver of carbon leakage. The higher the exchange rate risk is perceived; the more risk is associated with relocating production abroad. This will lower the incentive to move production abroad and hence reduce the risk of carbon leakage.

1.2.6 Product differentiation

The degree of international product differentiation is a key driver in determining the degree of leakage. This is so, since product differentiation affects the competitive environment and hence the ability for firms to pass on production cost increases to consumers. Consider first one product type produced in two different regions that has different value to consumers (e.g. home bias towards agricultural products). Such a differentiated product allows domestic producers to maintain a higher price since domestic consumers prefer domestically produced goods. Consider secondly a product, which is essentially the same across countries (such as refined oil, cement, aluminium etc.). A small price increase in such a homogenous good can spur a massive substitution towards the cheaper good. Such a homogenous good is known as a commodity, and most products that are normally recognised as being at the risk of carbon leakage are commodities.

Product differentiation is a key requisite for firms to be able to pass on price increases to consumers, and thus its ability to recover the cost induced by a CO_2 price without significantly undermining international competitiveness. In case of a homogenous commodity, domestic producers cannot increase the price in response to a tax increase without losing substantial market shares to foreign competitors. Consequently, the more homogenous a good is perceived to be, the larger the risk of carbon leakage. In fact, it has been shown that when the modelling framework is able to account for homogenous goods instead of differentiated goods, carbon leakage rates increase dramatically and may be well above 100 per cent.[16]

1.3 Leakage rates may change over time

An analysis of carbon leakage should take into account that leakage drivers (and brakes) may change over time. Consider, for example, the two variables: energy intensity and trade intensity. Both these factors have a tendency to change over time, and this change may, to a large extent, be driven by increases in the carbon price. While this point is acknowledged by the European Commission,[17] this is important when interpreting economic modelling of carbon leakage rates. Most models are linear in the carbon price, and do therefore not consider so-called tipping points that may occur, if leakage rates begin to increase when carbon prices reach a certain threshold, which is very likely from a theoretical point of view.

---

[16] See e.g. Babiker (2005) that uses homogenous Hekscher-Ohlin goods instead of differentiated goods modeled with Armington elasticities.

[17] The list of sectors and subsectors determined by the European Commission to be at risk of carbon leakage is updated app. every fourth year, and sectors and subsectors may be added each year through a Comitology decision.

Consider first *energy intensity*. While the emissions released from the chemical reaction required to generate clinkers from heating lime stone cannot be changed, the energy usage in the process may be, e.g. by investing in more innovative heating methods such as e.g. better insulated ovens. The higher the carbon price becomes, the higher the incentive to invest in innovation of energy efficient technologies becomes. The energy intensity in production is consequently expected to decrease.[18]

Consider now *trade exposure*. Trade exposure is a good measure of a product's tradability and whether or not it would be possible to move production abroad and serve the domestic demand from abroad. Current and/or historic trade exposure is however very much dependent on e.g. the relative prices at a given point in time, including import tariffs etc. The characteristics of most goods entail that they will be profitable to trade if the price differential becomes large enough. As long as the differential has not reached this "tipping-point", no trade will take place. But once the tipping-point has been reached, an industry may be massively exposed to international trade.

Two prime examples of industries, where the risk of carbon leakage has or is expected to increase substantially over time, are *cement production* and *electricity production*. Historically, *cement production* would not be considered to be exposed to a large amount of trade, especially due to its high weight-to-value ratio. However, as a result of relatively low transport costs and high energy prices, it has been possible to split up the cement production chain, and move the energy-intensive element in production (clinkers) to low-carbon price regions. In *electricity production*, tradability is determined by the available infrastructure. The lack of interconnectors between EU and third-countries has made carbon leakage risks outside EU largely unfounded. Interconnectors are however being established to e.g. Russia, Ukraine, and North Africa which will make the electricity industry heavily exposed to extra-EU trade, and substantially increase the risk of carbon leakage as a result of the large carbon price differential with these regions.

1.4 Size of leakage estimates

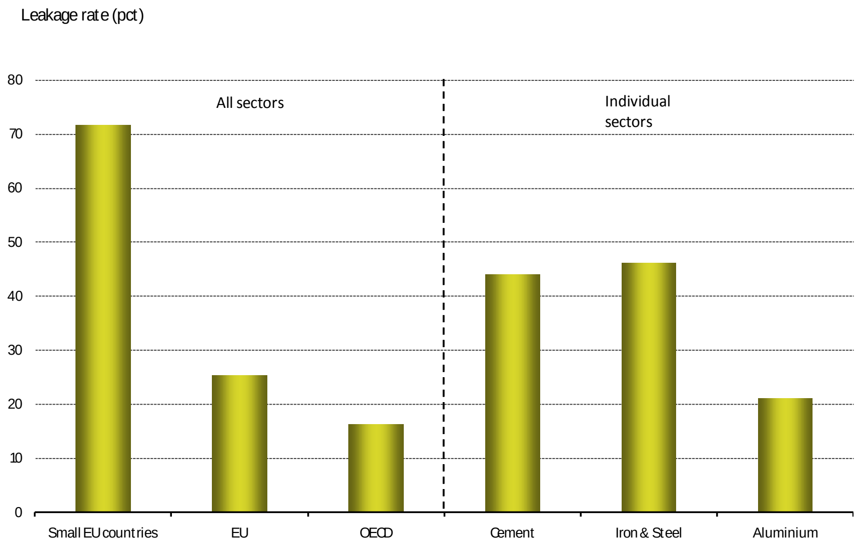
Much empirical work has attempted to measure leakage rates associated with different policies, e.g. compliance with the Kyoto targets or compliance with the ETS reduction targets. The higher the rate of leakage, the less effective and potentially the more distortive is the policy: It can re-

[18] As we stress above however, unilateral carbon price increases in geographically small regions will most likely not have a substantial effect on innovation, since these innovations may not be cost effective enough to be exported to low-tax regions.

sult in moving production to other countries that are *currently*[19] unable to compete on equal terms with domestic producers, leading to a less efficient use of world resources.

Typical macro estimates with conservative assumptions lie in the range of 10–30 per cent for large geographical areas such as the OECD or EU, while smaller geographical areas – such as Sweden and Denmark – tend to have significantly higher leakage rates of app. 60–90 per cent, cf. the left panel of Figure 6. Micro estimates tend to be higher than macro estimates and are often in the range of 40–50 per cent for energy intensive industries such as cement and iron and steel, cf. the right panel. Figure 6.

Figure 6: Leakage rates depending on region and sector



Note: The results are averaged over different model assumptions so the leakage rates are not directly comparable across size and sectors.

Source: Copenhagen Economics based on CPB (2011a), CPB (2011b), Antimiani et al. (2011), Copenhagen Economics (2011), OECD (2003), OECD (2009), Bohlin (2010), Babiker (2005), Burniaux & Martins (2000), Burniaux & Truong (2002), Böhringer et al. (2010), Demailly & Quirion (2008b), Gerlagh & Kuik (2007), Kuik & Gerlagh (2003).

A thorough review of different carbon leakage estimates will be conducted in Chapter 3.

[19] The fact that local producers are currently able to deliver goods to the domestic and global markets strongly suggests that they are at least as efficient as their foreign competitors. In some cases, part of the efficiency advantage comes from an optimal location (minimisation of transport costs and access to resources), while other cases are due to e.g. superior technologies.

2. Identification of Nordic industries at risk of carbon leakage

An important issue for policy makers is to determine which industries that are at the risk of carbon leakage. The approach used by the European Commission is to consider two factors: energy intensity and trade intensity. The industries at risk are the ones that fulfil one of the following three criteria:[20]

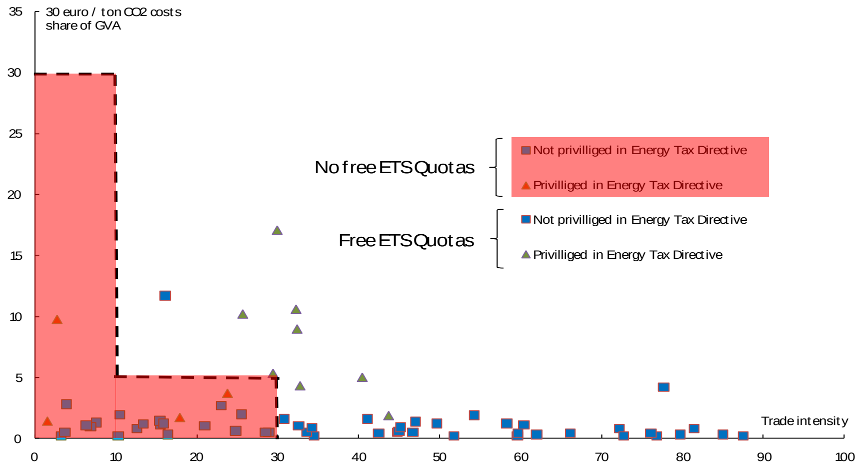
- The additional costs induced by carbon tax is at least 30 per cent of Gross Value Added (energy intensity)
- The Non-EU Trade intensity is above 30 per cent
- The additional cost induced by carbon tax is at least 5 per cent of Gross Value Added *and* the Non-EU Trade intensity is above 10 per cent

This approach is depicted in Figure 7. The industries that lie within the red shaded area are *not* deemed at risk according to the EU approach.

---

[20] Certain qualitative criteria are also applied to industries that do not fulfill the quantitative criteria.

Figure 7: Energy- and trade intensity



Note: Industries measured on a NACE 3-digit level. Energy intensity is here measured as amount of CO_2 emissions multiplied with an estimated ETS price of €30 pr. ton CO_2

Source: Copenhagen Economics based on data from Statistics Denmark and European Commission (2009). The ETS quota allocation is based on Directive 2009/29/EC amending 2003/87/EC. The Energy Tax Directive refers to Directive 2003/96/EC.

While this approach is a good starting point, we argue that a detailed analysis must include more variables than energy and trade intensity. The risk of carbon leakage should in fact be determined according to all the drivers listed in Chapter 1. Our basic argument is that trade intensity of a product is a consequence of the underlying drivers of carbon leakage, not a driver in itself.

In this chapter we will qualify the drivers from Chapter 1 and identify the industries in the Nordic countries that are deemed to be at risk of carbon leakage based on the information revealed by these drivers. We begin this chapter, however, by describing why the level of aggregation is important in any carbon leakage analysis.

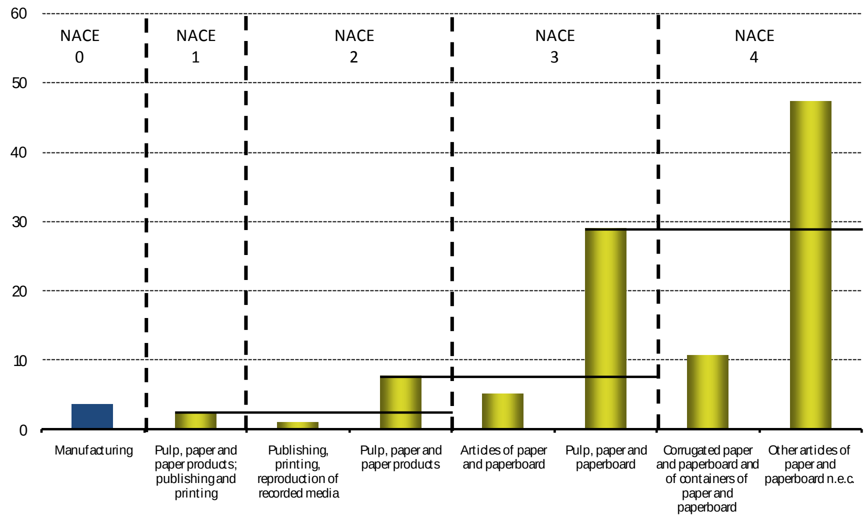
2.1 Importance of disaggregating the industrial structure

Energy intensity and other leakage-related factors can vary substantially between different processes in a production chain. This makes it important to consider such data on a detailed industry level. By using a level of aggregation that is "too high", one runs the risk of levelling out differences in an industry, leading to a loss of important information.

The paper industry is a good example of how certain energy-intensive processes would be ignored if one were to choose an inadequately detailed aggregation level, cf. Figure 8. The first two columns depict the energy intensity measured on a very aggregate industry level

(NACE 0: Manufacturing, and NACE 1: pulp, paper, and paper products). By moving to a higher level of disaggregation (moving right in the diagram), the energy intensity of different processes in the production chain becomes evident. In fact, the processes "pulp, paper, and paperboard", and the even more disaggregated "other articles of paper and paperboard" have significantly higher levels of energy intensity, which would be ignored by using a higher aggregation level.

Figure 8: Energy intensity in industrial subsectors – Paper industry



Source: Copenhagen Economics (2011), based on data from Eurostat, structural business indicators.

Based on these considerations, we will use data on a NACE-4 level to as large extent as possible. For energy intensity, this is available for almost all industries in all Nordic countries, except Iceland.

2.2 Our approach to identify leakage industries

In order to evaluate which Nordic industries that are at the risk of carbon leakage, we will take reference in the drivers and brakes identified in Chapter 1. Identifying industries at the risk of leakage is interesting in itself. Such industries are, at EU level, eligible both for free ETS allowances, various energy tax exemptions in accordance with the Energy Tax Directive and special treatment with respect to EU State aid guidelines. In order to apply different policy instruments effectively and efficiently, determining the industries at risk of leakage is crucial. When we have established the industries at risk of carbon leakage, we will evaluate the size of the leakage rate based on those industries through a modelling exercise in Chapter 3.

The primary driver of carbon leakage is the share of CO_2 used in production. Due to lack of sufficiently detailed data on CO_2 emissions, a good approximation is energy consumption.[21] We therefore begin by creating a list of industries (on a NACE-4 level) for each Nordic country based on industries that have an energy intensity higher than 10 per cent, measured by cost of energy in production as a share of value added. We then condense this gross list into a net list by using information from the remaining 4 drivers. The drivers and brakes, which we consider, including the data we use, are listed in Table 1.

Table 1: Drivers, brakes, and data sources

Drivers and brakes for leakage	Part of ranking	Data source
Drivers		
Share of energy costs in production	Gross list	Purchase of energy pr. industry. Data is available from Eurostat on NACE 4-digit for most industries but only on NACE-3 digit for some. Note: Data is not available for Iceland
Relative efficiency in production	Gross list	Value added at factor costs on a NACE-3 and NACE 4-digit (and energy use above) based on Eurostat detailed industry statistics. Note: Data is not available for Iceland
Possibility of splitting the individual processes	Net list	Qualitative assessment based on available knowledge in the literature
Brakes		
Transportability	Net list	Assessed by the weight-to-value ratio. Weight-to-value is measured from trade statistics on traded quantities and values, on a detailed product level. Available from the WITS database
Capital intensity	Long term net list	Assessed by the investment rate as a share of value added
Trade barriers	Net list	Tariffs from the WITS database
International product differentiation	Net list	Assessed by trade intensity. Data available from Eurostat on NACE-4 level

Source: Copenhagen Economics.

Data on several drivers, inter alia energy intensity, has not been available for Iceland. Iceland is a unique case in the sense that the share of electricity intensive industries (especially aluminium) is very large, and moreover that all electricity in Iceland is produced from renewable sources with no carbon emissions. Based on this, we expect Icelandic industries in general (electricity intensive industries in particular) to be largely unaffected by carbon prices. On the other hand, such industries are still responsive to other energy prices such as e.g. a tax induced increase in the price of electricity. This is further expanded in Box 1.

[21] This will be discussed further below.

Box 1. Expectations regarding carbon leakage in Iceland

Iceland has a relatively large bulk of electricity intensive industries out of total production.[1] This is largely due to aluminium production. This can be attributed to relatively low electricity prices in Iceland due to the vast amount of renewable energy used in electricity production, which on the margin generally is cheaper than electricity produced by fossil fuels.

All electricity production in Iceland (99.9%) stems from renewable energy sources. [1] This implies that electricity intensive industries, such as the aluminium industry, is largely unaffected by carbon prices. On the contrary, the relative cost of production of Icelandic aluminium decreases when carbon prices elsewhere increase. This implies that Icelandic aluminium industry is not at risk of carbon leakage, and may in fact even benefit from higher global carbon prices.

Renewable energy sources also constitute a large share (app. 80% in 2008) of total gross energy consumption.[1] Hence, Icelandic industry as a whole is also expected to be much less affected by carbon prices than most EU counterparts, and thus less at risk of carbon leakage.

While Icelandic industries may be less responsive to carbon prices, the industries are not immune to non-carbon energy prices. In fact, since a large bulk of total production comes from electricity intensive industries, higher prices on electricity, for example driven by a (non-carbon) tax, will reduce competitiveness of Icelandic industries. This will especially be the case for energy intensive firms, which in turn might reduce production. A shift in production out of Iceland would entail a large increase in emissions per unit of production due to the very low amount of carbon input in Iceland energy use.

Source: Copenhagen Economics based on University of Iceland (2009) and energy consumption data from Statistics Iceland.

2.3 Identifying industries in the Nordic countries at risk of carbon leakage

2.3.1 Producing the gross list

The gross list is a measure of industries in the different Nordic countries which will endure the largest increases in production cost from an increase in the energy price, e.g. through national energy taxes, increases in the price of ETS quotas or through cost of financing renewable energy investments (such as green certificate prices). We have included industries where the energy intensity[22] is above 10 per cent. This is to sort out industries that will not be affected much by increasing energy prices and consequently are less at risk of carbon leakage. If the energy intensity of an industry exceeds 10 per cent in a single Nordic country, it is added to the gross list. This is done without considering the granting of free allowances in the EU ETS, since the objective of this exercise is to evaluate industries at risk of carbon leakage prior to EU "anti-leakage" measures.

When considering energy intensity, we look at the cost of energy input. The correct measure would in fact be the cost of fossil fuel input, since direct renewable energy inputs are not directly affected by a carbon tax. However, the real issue is the extent to which carbon taxes affect the energy costs facing enterprises; and that depends on a number of different issues. In the Nordic power generation system, the marginal producers in the electricity system are gas and coal plants. Hence, the price of electricity is determined by the price of fossil fuel inputs, which implies that the actual input mix is less important for electricity users, and that energy intensity is a reliable approximation, at least in the long run. This is discussed more thoroughly in Chapter 3.

The gross list contains a total of 40 industries, cf. Table 2. These industries may be energy intensive in several Nordic countries or in a single Nordic country. While industries such as manufacture of paper and paperboard have high energy costs in all Nordic countries, some industries such as manufacture of distilled potable alcoholic beverages are only energy intensive in one country (Finland).

Table 2: The gross list – energy intensive industries. Purchase of energy products as a share of value added

Nace	Industry	Denmark	Finland	Sweden	Norway
152	Processing and preserving of fish and fish products	14%			10%
1531	Processing and preserving of potatoes			24%	13%
154	Manufacture of vegetable and animal oils and fats	18%			
155	Manufacture of dairy products		12%		
1562	Manufacture of starches and starch products	13%		72%	
1571	Manufacture of prepared feeds for farm animals		16%		13%
1583	Manufacture of sugar		34%		
1591	Manufacture of distilled potable alcoholic beverages		11%		
1597	Manufacture of malt	15%	24%		
172	Textile weaving		20%		
173	Finishing of textiles	13%	14%	13%	
1753	Manufacture of non-wovens etc., except apparel		30%		
191	Tanning and dressing of leather				10%
201	Sawmilling and planing of wood		14%	14%	
202	Man.of veneer sheets, plywood, laminboard etc		19%	20%	17%
2111	Manufacture of pulp		18%	33%	32%
2112	Manufacture of paper and paperboard	34%	49%	41%	52%
2122	Manufacture of household and sanitary goods etc.		20%		22%
232	Manufacture of refined petroleum products			18%	
2411	Manufacture of industrial gases	12%	33%		

[22] Measured as cost of energy input in production as a share of value added, which is not entirely the same measure used by the Commission.

Nace	Industry	Denmark	Finland	Sweden	Norway
2412	Manufacture of dyes and pigments		23%		56%
2413	Manufacture of other inorganic basic chemicals		33%	33%	24%
2414	Manufacture of other organic basic chemicals		12%	18%	23%
2415	Manufacture of fertilizers and nitrogen compounds		18%		66%
2416	Manufacture of plastics in primary forms	10%	19%	18%	19%
2441	Manufacture of basic pharmaceutical products		26%		
261	Manufacture of glass and glass products	13%	11%	17%	10%
2626	Manufacture of refractory ceramic products				19%
264	Manufacture of bricks, tiles etc.	24%	40%	21%	53%
265	Manufacture of cement, lime and plaster		35%	46%	25%
2662	Manufacture of plaster products for construction purposes		30%		30%
2664	Manufacture of mortars				10%
2682	Manufacture of other non-metallic mineral products		16%	19%	
271	Manufacture of basic iron and steel and of ferro-alloys		14%	24%	35%
272	Manufacture of tubes			13%	
2742	Aluminium production		11%	28%	41%
2744	Copper production		21%	20%	
2745	Other non-ferrous metal production				26%
275	Casting of metals	16%	11%	12%	9%
2951	Manufacture of machinery for metallurgy		10%		

Source: Copenhagen Economics based on Eurostat data.

Not all industries that have high energy cost are necessarily at risk of carbon leakage. In addition, industries with medium energy intensity can be more at risk of leakage than industries with high energy intensity when other characteristics are taken into account. To account for this, we apply the drivers identified in Chapter 1 to the industries listed in Table 2 in order to identify the sectors that are the most at risk of carbon leakage.

2.3.2 Quantifying the leakage drivers

In order to condense the gross list, we consider three drivers in addition to energy intensity: transportability (measured by weight/value ratio), trade barriers (measured by import tariffs), and international product differentiation (measured by trade intensity). Moreover, we also consider the size of the industries, in order to filter out industries that have a negligible economic importance in the Nordic countries. In addition to this, we have applied knowledge on whether industries can split up and outsource part of the production process.[23] Finally, we also include information on capital intensity in order to evaluate the time horizon of leakage in these industries.

For each industry in the gross list, we have assigned a quantitative score for every driver. In this way, we are able to isolate what drives leakage in each particular industry, which can provide information on which

[23] It has not been possible within the scope of this study to obtain sufficient sector specific information to make a high-quality evaluation. Instead, we have qualitatively evaluated the industries where information is readily available, such as e.g. the classic example of outsourcing the production of clinkers from cement production.

policy instruments will be most effective in various industries. The scores (where 1 is not driving leakage risk and 5 is driving leakage to a very large extent) are summarised for all industries in the gross list in Table 3. The methodology used to assign the scores is described in Box 2.

Table 3: Quantifying the drivers and brakes

NACE	Industry	Energy intensity	Product differentiation	Transportability	Trade barriers	Economic importance
152	Processing and preserving of fish and fish products	1	5	4	3	5
1531	Processing and preserving of potatoes	3	2	1	3	2
154	Manufacture of vegetable and animal oils and fats	2	3	3	4	3
155	Manufacture of dairy products	1	1	1	5	5
1562	Manufacture of starches and starch products	5	1	2	3	1
1571	Manufacture of prepared feeds for farm animals	2	1	3	3	4
1583	Manufacture of sugar	4	1	2	4	2
1591	Manufacture of distilled potable alcoholic beverages	1	2	4	5	2
1597	Manufacture of malt	3	2	2	5	1
172	Textile weaving	3	5	5	3	2
173	Finishing of textiles	1	5	5	3	2
1753	Manufacture of non-wovens and articles made from non-wovens, except apparel	4	3	5	3	1
191	Tanning and dressing of leather	1	5	5	4	1
201	Sawmilling and planing of wood; impregnation of wood	2	3	3	4	5
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	3	3	3	4	4
2111	Manufacture of pulp	4	3	2	5	5
2112	Manufacture of paper and paperboard	5	3	2	5	5
2122	Manufacture of household and sanitary goods and of toilet requisites	3	2	5	5	3
232	Manufacture of refined petroleum products	2	2	2	4	5
2411	Manufacture of industrial gases	4	4	2	3	3
2412	Manufacture of dyes and pigments	5	4	5	3	2
2413	Manufacture of other inorganic basic chemicals	4	4	3	3	4
2414	Manufacture of other organic basic chemicals	3	4	3	3	4
2415	Manufacture of fertilizers and nitrogen compounds	5	4	2	4	2
2416	Manufacture of plastics in primary forms	3	4	4	4	4
2441	Manufacture of basic pharmaceutical products	4	5	5	4	3
261	Manufacture of glass and glass products	2	2	1	5	4

NACE	Industry	Energy inten-sity	Product differen-tiation	Trans-porta-bility	Trade barri-ers	Eco-nomic impor-tance
2626	Manufacture of refractory ceramic products	2	4	5	4	1
264	Manufacture of bricks, tiles and construction products, in baked clay	5	1	3	3	1
265	Manufacture of cement, lime and plaster	5	1	1	4	3
2662	Manufacture of plaster products for construction purposes	4	1	1	4	1
2664	Manufacture of mortars	1	1	1	5	2
2682	Manufacture of other non-metallic mineral products n.e.c.	2	2	1	5	3
271	Manufacture of basic iron and steel and of ferro-alloys	5	3	4	5	5
272	Manufacture of tubes	1	4	4	5	4
2742	Aluminium production	5	5	4	4	5
2744	Copper production	3	5	3	4	3
2745	Other non-ferrous metal production	4	5	4	4	3
275	Casting of metals	2	5	4	5	4
2951	Manufacture of machinery for metallurgy	1	5	1	5	1

Source: Copenhagen Economics based on data from Eurostat and WITS.

Note that the drivers are quantified for the Nordic countries as a whole. Transportability and product differentiation are product specific measures and is not expected to vary across countries. Trade barriers are EU import tariffs and are therefore the same for all Nordic countries.[24] Moreover, it is unlikely that investment rates within the Nordic industries should consistently vary across the countries and the data do in fact confirms this picture. The only criteria that vary significantly between the Nordic countries are the relative economic importance and the energy intensity. While energy intensity already have been evaluated country-specifically, we have made a sector specific assessment in order to ensure that the economic importance criterion does not exclude sectors that may be important in a few (or one) Nordic countries but only has an insignificant importance for the Nordic region as a whole.

[24] There are no significant Norwegian import tariffs on the products in the industries that are included in the gross list.

Box 2. Methodology used to assign scores to each driver

The scores on almost all drivers are assigned based on a percentile approach. This means that generally the 20% highest observations are assigned the score "5", while the 20% lowest are assigned the score "1". In order to ensure that observations with similar values get the same score, we manually re-assign some scores. This has been the case for some industries being close to the "cut-off point" between percentiles. Moreover, qualitative assessments have also been necessary in order to capture specific industry characteristics, which are explained below. Finally, scores on the "trade barrier-driver" has been assigned through a slightly different approach, which is further elaborated below.

Product differentiation

In order to quantify product differentiation, we use data on trade intensity. If a product is homogenous across countries (and thus resembles a commodity) it will most likely be traded across borders. Hence a low degree of differentiation, and thus high risk of leakage, will be associated with a high trade intensity. Some qualitative evaluation has been necessary though. Consider e.g. cement industry, which is a fairly homogenous good (within specific types of cement). Since cement is heavy, it is quite expensive to transport and thus has low trade intensity, and hence would not receive an accurate score. Quantifying this driver has thus been coupled with a qualitative evaluation of the other relevant drivers for each industry.

Transportability

In order to quantify transportability, we use data on a product's weight-to-value ratio. The higher the weight-to-value ratio is, the higher the transport costs will be, and consequently the lower the products' transportability and the risk of leakage will be. We have also made specific qualitative assessment of the industries in order to assess if a product is in fact transportable based on product characteristics. While dairy products may be relatively cheap to transport, their durability is relatively low thus making them less transportable. The score on such products has manually been adjusted in order to capture this.

Trade barriers

In order to quantify trade barriers we use data on EU and Norwegian import tariffs. Import tariffs on products from the industries on our gross list are relatively small (most are zero). Since trade barriers are a break to carbon leakage, a high tariff will be associated with a low score. Since most tariffs are neglible we have assigned relatively large scores to this driver. This is also done to reflect that while import tariffs constitute a trade barrier to non-EU products, it does not prevent leakage within EU countries, includin g the Nordic countries. The exception is again Norway, which levies national import tariffs; however Norwegian tariffs on the industries we have identified in the gross list are of relatively minor size and thus importance.

Economic importance in the Nordic countries

In order to quantify the score on economic importance, we use data on each industry's share of value added out of total Nordic value added. This is not a driver of carbon leakage, but it is included in order to filter out industries that are largely negligible in the Nordic economy. The industries filtered out according to this criteria (the ones that has a score of 1) accounts for a share of Nordic value added between 0.00 pct. – 0.02 pct., and not above 0.02 pct. of value added in any Nordic country.

Source: Copenhagen Economics.

2.3.3 Producing the net list

The net list is constructed by applying the quantitative scores to the industries in the gross list in order to filter out the industries that had the lowest scores and thus were at the lowest risk of carbon leakage. The methodology used to filter out these industries is described in Box 3.

Box 3. Methodology used to select the net list

To determine the industries at most risk of leakage, we apply two selection criteria: a quantitative and a qualitative.

Quantitative evaluation

The quantitative criterion builds on the quantified drivers described in Table 3. The criterion is designed to filter out industries that, according to a single driver, are not at risk of leakage. That is, if an industry is characterised by for example a high weight-to-value ratio it will not be deemed at risk of leakage, even though other drivers may indicate that this should be the case. If one driver is given the score "1", the industry will therefore as a general rule *not* be included to the net list. The net list is therefore derived from industries that score higher than "1" on all criteria. For industries that have a sufficiently high capital intensity however, these are not included in the short run net list, since it takes time to depreciate existing capital stock. Industries with a capital intensity score of 1 or 2 will not be included in the short run list, but may be included in the long run list.

While the quantitative method is a good starting point, there may be nuances of complex industries that it does not capture. Hence, we also conduct a qualitative evaluation.

Qualitative evaluation

In order to make sure that the quantitative criterion does not include industries that are not at risk of leakage, and more importantly filter out industries that are in fact at the risk of leakage, we make a qualitative assessment of all the industries on the gross list. This evaluation captures situations where the quantitative evaluation have not taken due ac-count of specific industry features. Our qualitative evaluation e.g. considers if some proc-esses can potentially be split and outsourced. In these cases, an industry may in fact be at the risk of leakage even though it e.g. has a high weight-to- value ratio. Moreover, we have given special attention to industries which are excluded from the net list based on one quantitative score alone. Such industries may be included in the net list nevertheless if all other criteria weigh sufficiently high.

Source: Copenhagen Economics.

By applying this methodology, we are able to identify the industries, which are at the highest risk of carbon leakage. Among these industries are paper and pulp, cement, aluminium and also fertilizers and nitrogen compounds, basic pharmaceuticals, and basic chemicals, cf. Table 4.

Table 4: **The net list – industries at risk of carbon leakage**

NACE	Industry
1520	Processing and preserving of fish and fish products
1562	Manufacture of starches and starch products
1583	Manufacture of sugar
172	Textile weaving
2020	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards
2111	Manufacture of pulp
2414	Manufacture of other organic basic chemicals
2415	Manufacture of fertilizers and nitrogen compounds
2416	Manufacture of plastics in primary forms
2441	Manufacture of basic pharmaceutical products
2626	Manufacture of refractory ceramic products
265	Manufacture of cement, lime and plaster
2710	Manufacture of basic iron and steel and of ferro-alloys
2742	Aluminium production
2744	Copper production
2745	Other non-ferrous metal production
275	Casting of metals

Source: Copenhagen Economics.

Almost all of these industries were deemed by the European Commission to be at significant risk of carbon leakage based on the Commission's quantitative criteria (energy intensity and trade intensity). Three industries (manufacture of veneer sheets, plywood etc, manufacture of plastics in primary form, and manufacture of bricks, tiles etc.) made the Commission's list after a qualitative assessment.

2.3.3 Leakage risk in the longer run

The choices available to firms as a response to carbon pricing can vary substantially over time. Over the short to medium term, firms respond by decreasing carbon emissions for example by producing less output, choosing different raw materials and energy inputs, and/or by utilising available technological alternatives.[25] Over the longer term, however, firms have greater ability to seek more radical transformations of existing technologies. Moreover, and more importantly from a leakage perspective, firms can close down large scale capital intensive production facilities, and/or relocate these to lower carbon price-regions. This implies that while certain industries can seem heavily committed in a certain geographical market due to capital-intensive production facilities etc., and thus not at risk of leakage in the short run, the risk of leakage in the long run may nevertheless be high.

We take the time dimension into account by looking at how capital intensive an industry is. The higher the capital stock, the more investments will be foregone by abandoning a plant and moving to a different location. A good approximation to capital intensity is an industry's investment rate. However, this is only an approximation. If the capital stock e.g. is very durable and thus has a low depreciation rate, the capital stock may be high even though the investment rate is low. We expect this to be the case for e.g. aluminium that has a rather high capital stock but relatively low investment rate.

The industries in the gross list with the highest investment rates (manufacture of industrial gases) invest annually app. 36 per cent of value added, cf. Table 5. Note that Table 4 only depicts the 12 industries of the gross list that have investment rates above 15 per cent.[26]

Table 5: Industries with high capital intensity

Industry	Investment rate
Manufacture of industrial gases	36%
Manufacture of paper and paperboard	28%
Manufacture of malt	27%
Processing and preserving of potatoes	26%
Manufacture of household and sanitary goods and of toilet requisites	25%
Manufacture of refined petroleum products	21%
Manufacture of prepared feeds for farm animals	20%
Manufacture of dairy products	19%
Sawmilling and planing of wood; impregnation of wood	18%
Manufacture of non-wovens and articles made from non-wovens, except apparel	17%
Processing and preserving of fish and fish products	16%

Note: Only industries from the gross list with an investment rate over 15% are included

Source: Copenhagen Economics based on Eurostat.

[25] See e.g. IEA (2008b).

[26] The investment rate has been considered for all industries in the list.

These industries are not expected to reduce production through carbon leakage in the short run due to their relatively high capital intensity. However, such industries may reduce production in the longer run when the capital stock has been sufficiently depreciated and new investments are to be made.

Based on information on capital intensity, Table 6 depicts the industries that may not be at risk of carbon leakage in the short run, since they have large existing capital investments. However, these industries are likely to be at risk in the longer run, when the investments are sufficiently depreciated. These industries are chosen technically by satisfying the following two criteria:

1. Not included in the net list in Table 4 due to a high capital intensity
2. At risk of carbon leakage based on all other drivers and brakes

Table 6: The industries at long-term risk of carbon leakage

NACE	Industry
154	Manufacture of vegetable and animal oils and fats
201	Sawmilling and planing of wood; impregnation of wood
2112	Manufacture of paper and paperboard
2122	Manufacture of household and sanitary goods and of toilet requisites
2412	Manufacture of dyes and pigments
2413	Manufacture of other inorganic basic chemicals
271	Manufacture of bricks, tiles and construction products, in baked clay

Source: Copenhagen Economics.

2.4 Sectors of particular Nordic interest

2.4.1 Economic importance of the sectors in the Nordic countries?

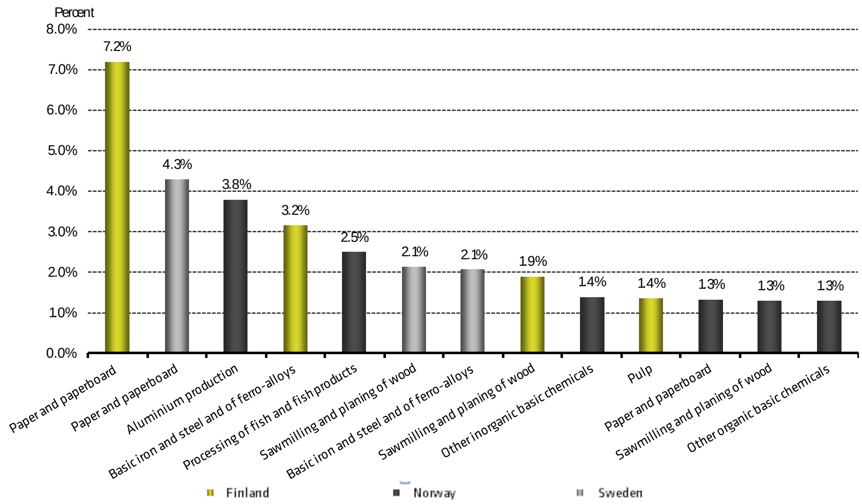
Measures to prevent carbon leakage are not free.[27] It is estimated that the Nordic countries will be able to generate app. €2 billion annually in revenue by auctioning 40 per cent of the total ETS allowances after 2013.[28] Giving away this amount of allowances for free thus constitutes a significant loss of revenue, bearing in mind, however, that such revenues may in fact be illusory over time if climate policy succeeds in reducing the demand for energy. The reason for this is that if production is displaced, demand for energy will decrease and the revenue potential of

[27] See the thorough discussion of efficiency of carbon leakage measures in Chapter 4.
[28] Nordic Council of Ministers (2009)

ETS allowances is reduced.[29] In order for policy makers to introduce expensive carbon leakage measures efficiently, it is important to know what the gains are to the economy of ensuring that production does not move abroad.

Of the industries determined to be at risk of carbon leakage in *both the long and short run*, it is primarily sectors related to paper and pulp industry (paper and paperboard, sawmilling, and pulp), iron and steel, aluminium, processing of fish, and chemicals that have a large importance in the Nordic economies, cf. Figure 9. We will refer to these industries as the *key leakage industries*.

Figure 9: Economic importance of leakage industries



Note: Value added as a share of total value added in manufacturing is calculated on a national level, and is not aggregated across the Nordic countries. No industry in Denmark on the net list has a share of value added that exceeds 1 per cent.

Source: Copenhagen Economics based on Eurostat.

The paper-related industry is the key leakage industry in both Finland and Sweden, where paper and paperboard, sawmilling, and pulp are responsible for more than 10 per cent of national value added in manufacturing in Finland and 7.5 per cent in Sweden. Moreover, iron and steel is also important, constituting 3.2 per cent and 2.1 per cent of value added in Finland and Sweden respectively. The industrial structure in Norway is somewhat different, where the key leakage industries are alumin-

[29] In this context it is very important that foregone revenue estimates are based on realistic long term price elasticities which take into account that production will be displaced.

ium, processing of fish, chemicals, but also paper and paperboard, and sawmilling. These industries are responsible for a total of 12.7 per cent of Norwegian value added. The industries included in the net list are not significantly economically important in Denmark. The share of value added for all industries deemed at risk of leakage in the Nordic countries is listed for all countries in the appendix.

Two additional observations can be made from Figure 9. *Firstly*, some industries deemed to be at risk of carbon leakage are more important to the economy than others. This suggests that if carbon leakage is sought prevented in order to protect domestic production and value creation, the industries listed in Figure 9 may give more bang-for-the-buck. *Secondly,* several industries at risk of leakage are present in more than one Nordic country. This suggests that leakage could in fact take place between the Nordic countries as a response to unilateral carbon taxation, since the underlying structures of these industries are evidently present.

2.4.2 Are some of these sectors only important to the Nordic countries?

The determination, by the European Commission, of industries considered at risk of carbon leakage has been constructed from a rules-based quantifiable approach supplemented with qualitative analysis where deemed appropriate. It cannot be ruled out that such qualitative analysis in the future may to some extent be inspired by Member States' interests. In this context, it is important for Nordic policy makers to know how the industry structure in other Member States may overlap with the Nordic industry structure.

Industries such as manufacture of aluminium, processing and preserving of fish and fish products, iron and steel, chemicals, and paper related production are the key Nordic industries at risk of leakage, cf. Figure 9. Except for organic chemicals, and iron and steel production, these industries primarily have an importance in East European countries, Greece, and Portugal, cf. Table 7. Organic chemicals are important in Belgium, Ireland and the Netherlands, while iron and steel are important in a large amount of other EU countries.

Table 7: Importance of Nordic industries in other EU countries

NACE	Industry	Important in these EU countries
152	Processing and preserving of fish and fish products	Latvia, Lithuania and Estonia
2010	Sawmilling and planing of wood; impregnation of wood	Austria, Latvia, Estonia, Lithuania and Romania
2111	Manufacture of pulp	Portugal
2112	Manufacture of paper and paperboard	Austria, Portugal, Slovakia and Slovenia
2413	Manufacture of other inorganic basic chemicals	None
2414	Manufacture of other organic basic chemicals	Belgium, Ireland and Netherlands
2710	Manufacture of basic iron and steel	Belgium, Bulgaria, Czech Republic, Germany, Greece, Spain, France, Italy, Hungary, Austria, Poland, Romania, Slovenia
2742	Aluminium production	Greece

Note: Note that data is incomplete for a few countries, namely: Czech Republic, Estonia, Ireland, Cyprus, Latvia, Malta and Slovakia.The selection criteria for deeming an industry important in another EU country is if it adds more than 1 per cent of national value added.

Source: Copenhagen Economics based on Eurostat.

3. Estimating carbon leakage

In this chapter we summarise some findings in the literature on carbon leakage. Particularly we underline that leakage estimates tend to vary across both different assumptions and more underlying methodological approaches. We also run our own illustratory model simulation using a linearised partial equilibrium model, and estimate the leakage rate to be at or above 100 percent for the Nordic industries at the highest risk of carbon leakage. A key explanation of this result is that the Nordic countries have a very low rate of carbon input in electricity production and a high level of energy efficiency in manufacturing firms' production as well as high conversion rate in fossil fuel based power plants.

3.1 Existing empirical research

3.1.1 Overview of carbon leakage rates in existing studies

Carbon leakage has gained much attention recently. However, estimates of leakage rates have varied across studies from largely negligible leakage rates, to rates over 100 per cent.[30] Part of the difference can be attributed to different choices of elasticities and deep parameters in different models. However, there are also several structural choices that can tell us something about the expected result. We have identified five elements that will tend to influence model results: 1) Scope of area with joint carbon pricing, 2) Size of price differential between regions, 3) Sector aggregation, 4) Degree of substitution, 5) Modelling total economy or individual sectors.

Scope of area with joint carbon pricing
While several different policy areas[31] have been studied in the literature, there has been a focus on especially carbon pricing in Annex I countries and the EU respectively. Much less focus has been given to smaller policy areas such as e.g. single countries with unilaterally high carbon pricing. Models do however show a very clear trend; the smaller the policy area

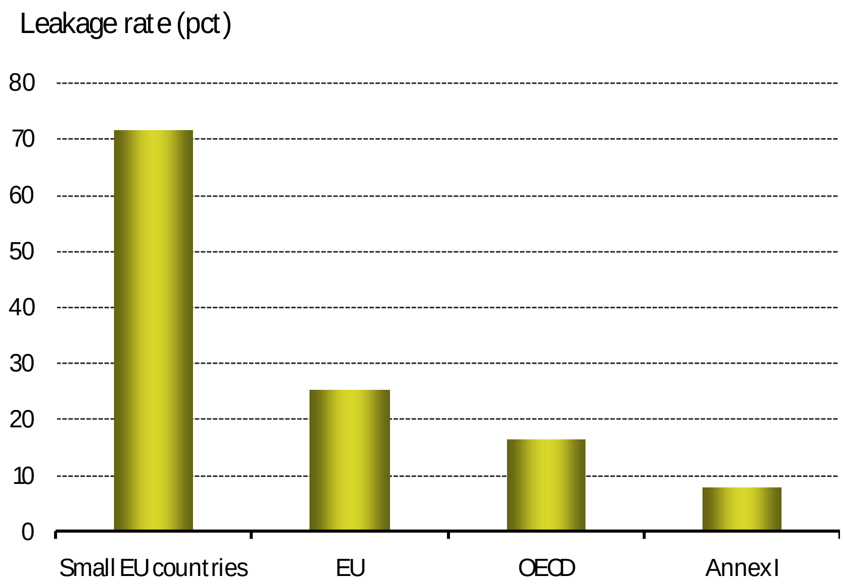
---

[30] Leakage rates above 100 per cent are found in the literature and occur due to specific assumptions. See e.g. Babiker (2005) where a leakage rate of 130 per cent is found for EU by assuming homogenous goods and imperfect competition.
[31] Defined as regions with a common carbon pricing policy.

the higher the leakage rates become Figure 10. By including more regions into the policy area the price differential between these regions is removed and thus fewer leakage opportunities exist. This argument becomes obvious when considering including a country such as China in e.g. the EU ETS. In such a case, the competitiveness of e.g. Chinese steel production would become more in line with EU producers, which consequently would reduce leakage.

When the policy area is increased, carbon leakage also changes character. While industry leakage is the most important channel for small policy areas, rebound leakage becomes increasingly important as the policy area's impact on the global energy demand is increased.

Figure 10: Leakage rates depending on region size



Note: We have included models that consider all sectors (not just one sector). Different models use different assumptions, and the presented results should be seen in this perspective. We have also applied an element of subjective judgement in order to make the results comparable. We have e.g. omitted the high leakage rates found by Babiker (2005) since these are derived from a homogenous good assumption. Instead Babiker's (2005) lower results assuming differentiated goods (Armington goods) have been included.

Source: Copenhagen Economics based on CPB (2011a), CPB (2011b), Antimiani et al. (2011), OECD (2009), Bohlin (2010), Babiker (2005), Burniaux & Martins (2000), Böhringer et al. (2010), Gerlagh & Kuik (2007), Kuik & Gerlagh (2007), Burniaux & Truong (2002), Copenhagen Economics (2011).

Size of price differential between regions

There are strong reasons to believe that leakage rates will be strongly influenced by the size of the carbon price differential. As argued in Chapter 1, small price differentials may have a large effect in markets dominated by easy-to-transport commodities with single world market prices such as e.g. sugar, aluminium, electronics etc. For such industries, a small carbon price differential can cause all production to close down. Technically this means that the leakage rate will be very high in the short run, and that it will not increase by much for carbon prices exceeding the initial increase. However, for industries dominated by heavy, differentiated goods, leakage may not occur until the price differential has exceeded a certain threshold. Consider for example the cement industry: Since cement (and most other goods) is cheaper to transport by boat than by road, coastal areas will be more exposed to competition than in-land areas. Studies show that there is a significant price difference between such areas.[32] This means that for a relatively small carbon tax in a policy area, only coastal cement production will be leakage exposed. This holds true until the carbon price reaches a level where foreign production can be competitive even in in-land areas.[33] This suggests that if models do not consider such "tipping points" in the carbon price, they may underestimate leakage exposure.

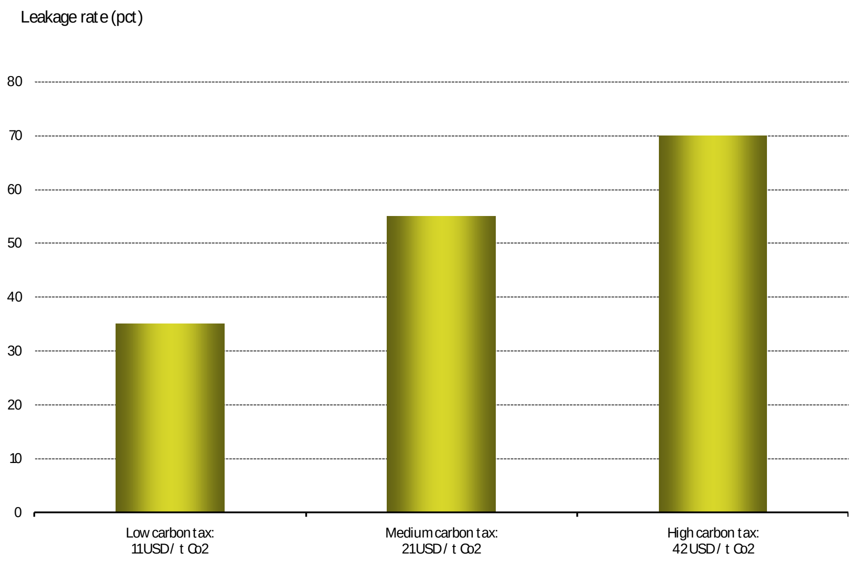
There are not many studies that explicitly consider this point. One study, considering the iron and steel industry in an EU/Japan common policy area finds, that while the leakage rate is 35 per cent for a carbon tax of 11 USD / t CO_2, the leakage rate increases to 55 per cent and 70 per cent for carbon taxes of 21 and 42 USD / t CO_2 respectively, cf. Figur 11.[34] This implies that the rate of carbon leakage increases in the carbon price, implying that production may dissolve at a much faster rate when carbon prices reach a sufficiently high level.

[32] See Walker (2006).

[33] See e.g. Ponssard and Walker (2008).

[34] The authors also find that the carbon leakage rate is increasing over time.

Figure 11: Leakage rates depending on level of carbon tax



Note: Iron and steel industry when EU/Japan for a carbon price differential between EU/Japan and the rest of the world.

Source: Copenhagen Economics based on Gielen & Moriguchi (2002).

Sector aggregation

Sector aggregation matters for leakage rates in the same way that it matters for defining industries at risk of leakage, namely by averaging out sector specific leakage rates when considering more aggregate industries. Most studies, based on general equilibrium models, do indeed not isolate specific industry sectors (or subsectors), as underlying databases are not disaggregated enough.[35] Some studies have found that the rather modest leakage rates coming out of general equilibrium analysis might, at least partially, be explained by the high level of sector aggregation. Leakage rates are more pronounced in highly carbon-intensive sectors, but these effects may be drowned out in very large aggregate sectors.[36] This suggests that even though the leakage rates predicted in most models may be modest, carbon leakage may be substantially higher for single subsectors. This in turn may also imply that leakage at macro level is higher than suggested by models using a too aggregated approach.

---

[35] See e.g. IEA (2008b).

[36] See e.g. Warwick & Wilcoxen (2008) and Fisher et al. (2010), cited in Rutherford (2010).

Degree of substitution in international trade

There is evidence that consumers do not always see imported goods as perfect substitutes for domestically produced goods.[37] This can have several reasons, e.g. that consumers have more information on environmental and ecological regulation of domestic groceries than foreign groceries, or if consumers want to support domestic producers etc. In models, this is captured by the so-called Armington elasticities. Such elasticities imply that the loss in demand and market shares by increasing prices domestically is lower than if foreign goods had been perfect substitutes.[38]

Even though the Armington specification may be appropriate for several types of goods, it is less appropriate for commodity-goods which tend to be much more homogenous than for example locally grown vegetables. Examples of commodities are refined oil, chemicals, aluminium, steel and other metals, rubber, paper, and even food products such as sugar, spices, and to some extent wheat. Such products are traded around the world at very small price differentials. This means that producers cannot pass on local carbon taxes to consumers without losing significant market shares, which leads to carbon leakage. Even though this is the case, most models continue to use Armington elasticities even for commodities such as chemicals and aluminium. This will tend to underestimate carbon leakage for homogenous goods, which does not become less important considering that several of the homogenous goods have very energy-intensive production processes. In fact, a study has shown that changing this specification can increase the leakage rates dramatically from 20-25 per cent to 60-130 per cent, cf. Table 8.

Table 8: Homogenous and differentiated goods

Region with climate policy	Good characteristic	Degree of competition	Leakage rate (pct)
OECD	Homogenous good	Imperfect competition	130
OECD	Homogenous good	Perfect competition	60
OECD	Differentiated good	Imperfect competition	25
OECD	Differentiated good	Perfect competition	20

Note: The leakage rate increases when competition is imperfect. This is due to the effect that under imperfect competition there is not produced enough of the good. When the competitiveness of the monopolised industry is reduced by a carbon tax, the level of competition is increased which leads to an increase in the production of the good and hence an increase in emissions in low-carbon tax regions.

Source: Copenhagen Economics based on Babiker (2005).

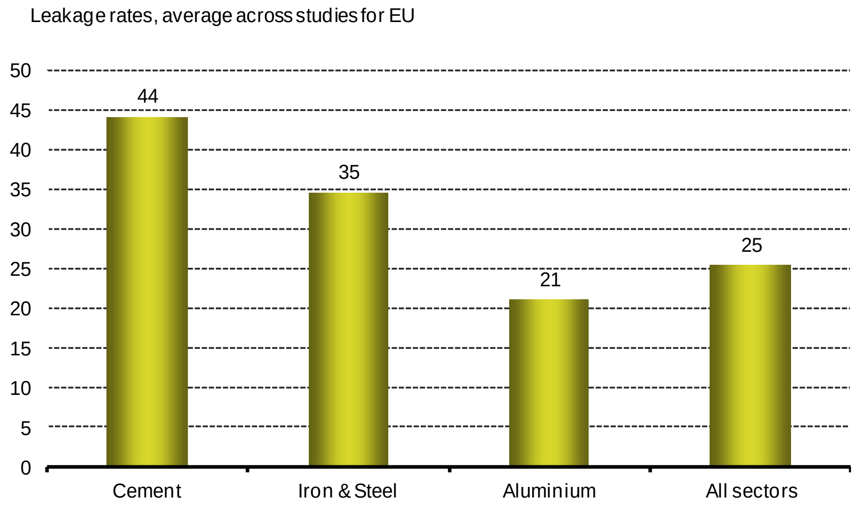
[37] This translates into a substitution elasticity between domestic and imported goods that is not infinite.

[38] If the goods had been perfect substitutes, even very small price differentials would shift the entire demand to the cheapest product.

Type of model – total economy or sector specific

Leakage rates seem to depend on whether models focus on the total economy (by using e.g. general equilibrium models) or have a more sector-specific focus (by using e.g. partial equilibrium models). Data on this issue rather consistently suggest that sector specific studies seem to estimate higher leakage rates than general equilibrium models.[39] This holds true for EU, cf. Figure 12 but also for OECD and Annex I countries, cf. Figure 13. While the average total sector leakage rate for EU is 25 per cent, both the cement and iron and steel sector have leakage rates above this. In fact some studies find that the leakage rate for EU cement can be as high as 70 per cent[40] and as high as 75 per cent for iron and steel.[41] The only result available for EU aluminium seems to suggest that the leakage rate is 21 per cent.

Figure 12: Sector specific and total economy results, EU



Note: The figure depicts leakage rates that have been averaged across different studies. 4 studies were found on cement, 4 on iron & steel, 1 on aluminium, and 3 on all sectors.

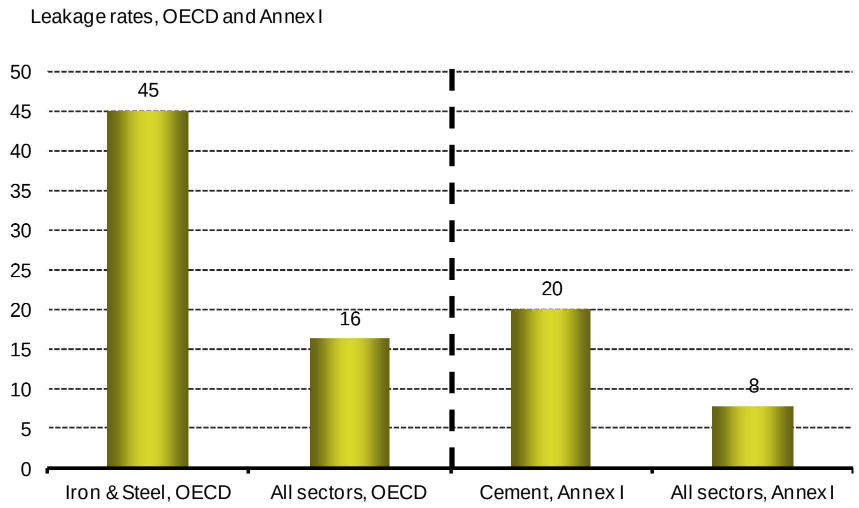
Source: Copenhagen Economics based on CPB (2011a), OECD (2009), Böhringer et al. (2010), Ponssard & Walker (2008), Monjon & Quirion (2009), Demailly & Quirion (2006), Demailly & Quirion (2008a), IEA (2008a) and Ritz (2009).

---

[39] This is also a point made in the literature by e.g. Rutherford (2010).
[40] Ponssard and Walker (2008).
[41] Ritz (2009).

Fewer sector-specific studies are available for OECD and Annex I countries, but the available evidence seems to convey the same conclusion: that leakage rates for specific sectors may be substantially larger than total economy estimates suggest, cf. Figure 13.

Figure 13: Sector specific and total economy, OECD and Annex I



Note: The figure depicts leakage rates that have been averaged across different studies. While 5 studies were used to calculate Annex I all sectors, 3 were available for OECD all sectors, and only 1 for iron & steel OECD, and cement Annex I respectively.

Source: Antimiani et al. (2011), OECD (2003), OECD (2009), Burniaux & Martins (2000), Demailly & Quirion (2008b), Gerlagh & Kuik (2009), Burniaux & Truong (2002), Babiker (2005), Kuik & Gerlagh (2003).

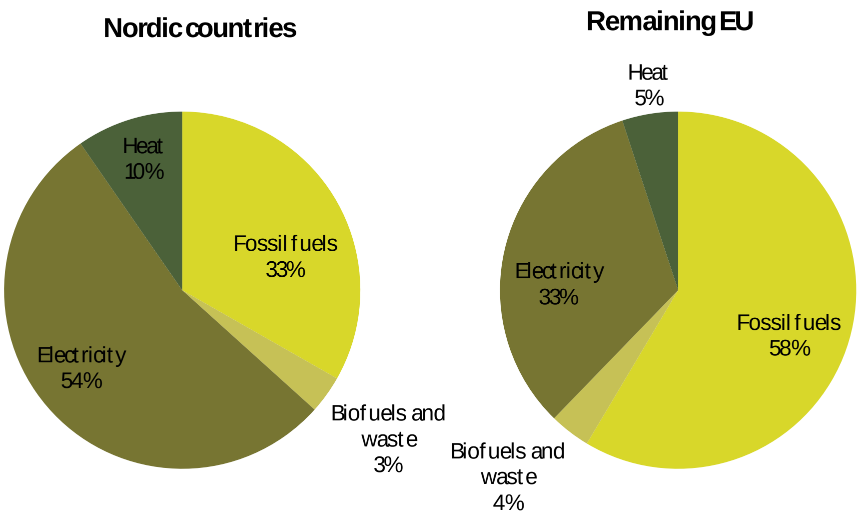
3.2 Our approach to estimate carbon leakage

We base our carbon leakage estimate on the simulation of a partial equilibrium model, which has the advantage of providing a simple and intuitive explanation for the level of carbon leakage. An important input in this model is the net CO_2 emissions in the sectors most at risk of carbon leakage, cf. chapter 2. In the model simulation in Section 3.3, we find that leakage rates of the Nordic industries at risk of leakage can be very large, and exceed 100 per cent. There are several reasons for this: 1) Nordic industries are more energy efficient, 2) Nordic industries consume a relatively higher share of electricity and biofuels as energy input, and 3) the indirect emissions from the production of electricity are very low in the Nordic countries. The remainder of section 3.2 is focused on elaborating these claims.

3.2.1 Importance of electricity in Nordic industries

Electricity is a widely used source of energy in the Nordic countries. While electricity constitutes only 33 per cent of the energy input in an average European manufacturing industry, it constitutes 54 per cent in an average Nordic industry, cf. Figure 14.

Figure 14: Composition of energy consumption

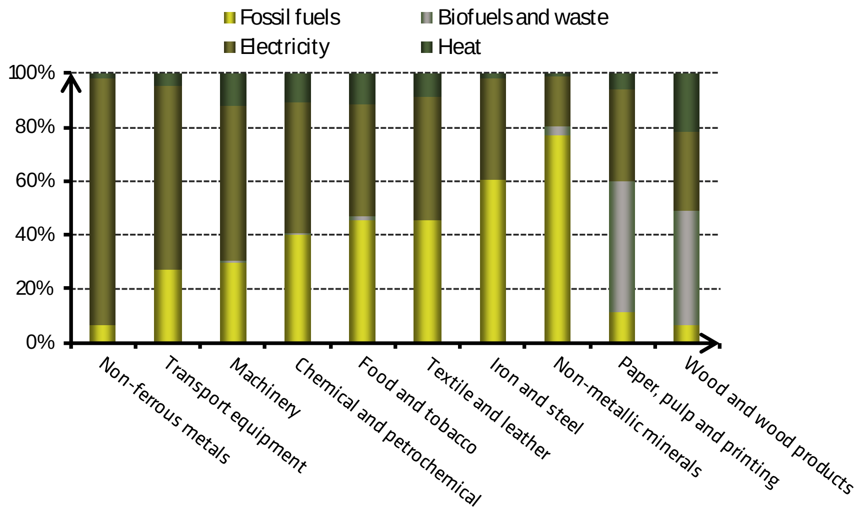


Note: Industries are measured at a NACE-2 aggregation level. Paper, pulp and printing industry has been excluded as it uses exceptionally high amount of biofuels and waste energy sources (89% in Nordic countries and 33% in remaining EU countries). This is most likely due to usage of large amount of wood-related waste products

Source: Copenhagen Economics based on OECD iLibrary- IEA World energy balances

This overall picture however conceals large variation between industries. While electricity is dominant in manufacture of e.g. chemicals, non-ferrous metals (such as aluminium), and machinery, fossil fuel inputs are dominant in especially manufacturing of iron and steel, and non-metallic minerals, cf. Figure 15. Paper, pulp and printing, and wood and wood products consume a significant amount of renewable energy input which is due to the availability of waste products associated with the processing of wood.

Figure 15: Energy consumption per energy type in Nordic industries



Note: Industries are measured at a NACE-2 aggregation level.

Source: Copenhagen Economics based on OECD iLibrary- IEA World energy balances

Due to the large dependence on electricity in Nordic industries, it is important to assess the average CO_2 emissions generated by producing electricity in the Nordic countries. Relative to the remaining EU countries, the CO_2 content in Nordic electricity production is substantially lower. In fact, while the average Nordic CO_2 emissions pr. GWh is 90 t CO_2 (masking a variation from 6 in Norway and 19 in Sweden to 413 in Denmark), the CO_2 emissions pr. GWh in the remaining EU countries is 517 t CO_2 pr. GWh, cf. Table 8. The low share of CO_2 in Nordic electricity is mainly due to a very large share on non-fossil sources of input in electricity production such as hydro, nuclear and other renewable (inter alia wind), cf. Table 9.

Table 9: CO_2 emissions per GWh electricity production, 2007

Country	tCO_2/GWH	Electricity production from			
		Fossil	Nuclear	Hydro	Other renewables
Denmark	413	39%	0%	0%	18%
Sweden	19	2%	45%	47%	4%
Norway	6	1%	0%	98%	1%
Finland	99	8%	7%	4%	75%
Nordic region	90	8%	13%	33%	38%
Remaining EU	517	55%	28%	7%	5%

Source: Copenhagen Economics based on data from CARMA (www.carma.org).

In addition to the low share of fossil fuel in electricity production, Nordic fossil based power plants are relatively energy efficient. This is especially the case in Denmark, where e.g. each unit of coal input into a power plant generates app. 0.43 units electricity/heat compared with 0.37 in the average OECD country, cf. Table 10.

Table 10: Efficiency of electricity production in public electricity and combined heat and power plants

Country	Efficiency of electricity production from Coal	Efficiency of electricity production from Natural Gas	Efficiency of electricity production from Oil
Denmark	43%	45%	40%
Sweden	40%	35%*	37%
Norway	34%	-	30%*
Finland	39%	49%	35%
OECD	37%	45%	37%

Note: The efficiency is calculated as sum of electricity and heat production from public power plant divide by the amount of fuel. The (*) indicates that observations from 1990 were used instead of an average 2001-2005

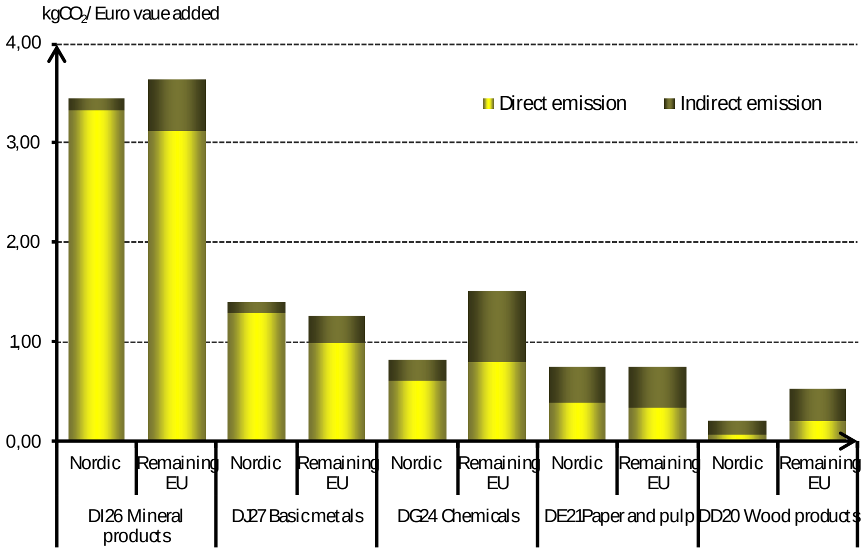
Source: IEA (2008c); Energy efficiency indicators for public electricity production from fossil fuels, IEA information paper

3.2.2 Relative size of CO_2 emissions

We have so far been using energy intensity as our main indicator for carbon leakage risk. Due to variations in energy prices, the fuel mix, and the energy efficiency of production, this indicator does not provide much information on the level of actual emissions. Unfortunately, data on actual CO_2 emissions are not available on a particularly detailed aggregation level. Consequently, we base our assessment on direct CO_2 emissions on a fairly aggregate level, and data on the consumption of electricity and heat.

Based on the aggregate CO_2 data, it turns out that the Nordic industries are relatively more CO_2-efficient than the remaining EU, except in the basic metals industry. This can primarily be attributed to the low CO_2 content of electricity produced in the Nordic countries, since direct CO_2 emissions pr. value added is actually quite high in the Nordic countries, cf. Figure 16.

Figure 16: CO_2 emissions as share of value added at NACE-2



Source: Copenhagen Economics based on Eurostat

In order to run our model simulations on the disaggregated industries which we have identified in Chapter 2, we need to align these data on CO_2 emissions with the NACE-4 level of aggregation used in Chapter 2. The methodology used for this is described in Box 5.

Box 4. Estimation of CO_2-emissions at a NACE-4 level of aggregation

Whereas data on energy purchase is readily available at a NACE-4 level of aggregation, this is not the case for data on the actual consumption of energy.

In order to estimate data for CO_2 emissions at NACE-4 level, we apply some assumptions to the available data. Consider first the available data:

- Data on *direct* CO_2 emissions from combustion of fuels is available at a NACE-2 level of aggregation
- Data on *indirect* CO_2 emissions are calculated based on actual consumption of electricity at NACE-2 level, and the CO_2 content of national electricity production, cf. *Table 8*

This data, which is used in *Figure 16*, are subsequently distributed onto NACE-4 level in proportion to the total energy purchase in order to estimate the emissions of the industries most at risk of carbon leakage. The rather crude assumption is that the fuel mix and energy efficiency does not vary for industries below the NACE-2 level.

The lack of data, and the following assumption, would pose a problem if the objective of this study had been to present a detailed cross sector analysis, with specific leakage rates for specific industries. However, since we present an aggregate measure for the group of industries most at risk of leakage, we do not consider it a course for much concern.

Source: Copenhagen Economics.

Our focus in this exercise is on the industries identified in chapter 2 to be at the most risk of carbon leakage. Narrowing our focus to these sectors reveal that these Nordic industries in fact emit even less CO_2 per value added relative to their EU counterparts. On average for the long run net list, 2.08 kg CO_2 are emitted per euro of value added in the Nordic countries, whereas it is 1.7 times higher if production takes place in the remaining EU. Such differences in carbon-efficiency is a key driver in carbon leakage, and can potentially lead to a leakage rate higher than 100 per cent which implies that overall global emissions increase in response to stricter climate policy.

Table 11: CO2 per value added in leakage industries

	Kg CO_2/ value added	
	Nordic	**Remaining EU**
Net list, short run	2,15	3,75
Net list, long run	2,08	3,63
Gross list	2,36	3,83

Source: Copenhagen Economics based on Eurostat

3.3 Estimated carbon leakage ratio

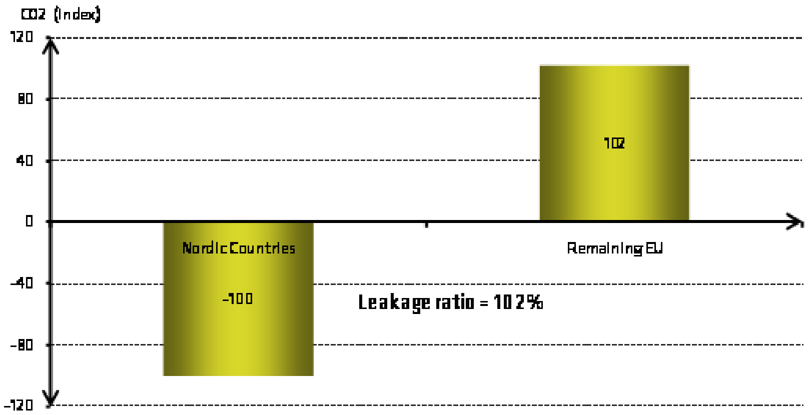
Our simulation results are based on a linearised partial equilibrium model.[42] It has the advantage of being fairly easy to understand and interpret, but this does come at the loss of generality. Such a model is best suited to describe marginal effects around an assumed equilibrium.

Building on the findings of this report, including the industries at most risk of leakage in the Nordic countries and data on both direct and indirect CO_2 emissions, we estimate the leakage rate of the Nordic *key leakage industries* to be 102 per cent, cf. Figure 17. This implies that for every 100 t CO_2 that is abated in the Nordic countries, emissions outside the Nordic countries will increase by 102 t CO_2.[43] This result is primarily

[42] The model specifications are presented in the Appendix.
[43] The model only considers other EU countries.

driven by the high energy efficiency in the Nordic industries, and the low CO_2 content in electricity produced in the Nordic countries.

Figure 17: Carbon leakage for Nordic industries most at risk



Note: The level of abatement is a result of an assumed CO_2 price differential of 33 %. This differential however, has no impact on the leakage rate, since this is assumed linear in the price differential. Even though the Nordics and the rest of EU are covered by the ETS, the implicit CO_2 price differential between these regions is positive. This is because the Nordic countries generally impose higher energy taxes and impose a large subsidy to renewable energy producers through the electricity bill.

Source: Copenhagen Economics based on model simulation

The model results presented above are meant to illuminate and explain the existing effects. Our conclusion is that a large number of studies tend to underestimate the size of leakage, particularly from a long term perspective. In line with other studies focused on core leakage sectors, we do estimate the leakage ratio to be at around, and even exceeding, 100 % by a small margin. Moreover, the model simulations are based on an assessment of carbon leakage between the Nordic countries and the rest of EU. While the EU constitutes a very large trading partner for the Nordic countries, leakage to third countries is a real and growing concern. Since several large non-EU countries have an even higher CO_2-content per value added, we expect carbon leakage rates to be even higher when comparing the Nordic countries with non-EU countries.

Nordic leakage exposed industries tend to consume most of their energy demand as electricity from the grid, while similar firms in other EU countries tend to produce more of their own energy based on fossil fuels. Moreover, fossil based power plants in Nordic countries are relatively efficient. Therefore, every unit of energy intensive production moved from the Nordic area to other parts of EU, or other parts of world, are likely to be followed by a net increase in carbon emissions. This may in fact drive carbon leakage rates above 100 per cent, if demand is not very price elastic.[44] Partly this could be offset by increased exports of "clean" electricity to other EU countries, but due to the relatively limited grid infrastructure in Europe, that would only be feasible through costly grid upgrades. An analysis of this perspective in greater detail would require a specific power market model to capture electricity trade within and outside the region, including decisions to increase or decrease capacity in different types of power generation (atomic power, wind mills, hydro, coal and gas plants). That goes well beyond the sphere of this project.

[44] In this case, consumers would reduce demand significantly, thus not giving incentive to build up foreign supply (which is marginally more expensive – otherwise it would have been consumed in the first place)

4. Policy recommendations

Industries in the Nordic countries are heavily exposed to carbon leakage, as documented by Chapters 2 and 3. The question we address in Chapter 4 is: what is the appropriate policy response to this challenge?

Firstly, we recap the characteristics of existing, and discussed policy options to deal with carbon leakage (section 4.1 “Basic recap of policy options”). *Secondly*, we review how these policy options score on a number of success criteria that we set up for such measures from both a theoretical as well as more practical level (section 4.2 “Evaluating anti-leakage measures”). *Thirdly*, we provide our overall recommendations for the course of action to be taken by Nordic countries in national, Nordic, EU, and global perspectives (section 4.3 “Overall policy recommendations”).

4.1 Basic recap of policy options

There are currently a wide range of measures in place in Nordic and EU countries to reduce the extent of carbon leakage. Our focus in this report is on measures that are relevant in a wider Nordic and international policy context and relevant in particular for the discussion of the climate policy framework after 2012.

The EU has provided a framework that directly regulates measures to reduce industrial carbon leakage. Specific regulation is designed in the EU ETS (allocation of free allowances) and the EU Energy Tax Directive (application of reduced rates of energy taxes). Compensating industries for high electricity costs is addressed under the EU State aid rules and new guidelines for this is currently being contemplated.[45]

There are discussions at the more global level about other types of policy options. Two options that have been discussed quite heavily are border tax adjustment mechanisms (BAMs) and sector based Clean Development Mechanisms (sector CDM).

[45] See e.g. http://ec.europa.eu/competition/consultations/2011_questionnaire_emissions_trading/index_en.html

Before we evaluate the effectiveness and efficiency of such measures in section 4.2, we go through the main characteristics of the following policies:

- EU ETS
- Energy taxation and financing of renewable energy investments
- Compensating electricity intensive industry
- Border adjustment mechanisms and sector CDM

4.1.1 EU ETS

This focus of this section is on the post-2012 functioning of ETS. Recognising the risk of carbon leakage, industries at risk of carbon leakage are provided with free allowances. The risk of carbon leakage is evaluated based on energy intensity and trade intensity as explained in Chapter 2. The amount of allowances provided to each firm depends on a benchmark established for each industry, i.e. if a firm can use energy more efficient per unit of output, then, in principle, it receives more allowances than it needs to serve its current level of production, cf. Box 5. The actual amount of allowances is based upon the historical production within the activities. The continued allocation of allowances is conditional on continued production, and new entrants will be provided with allowance from a reserve pool according to a benchmark basis. Industries at risk of carbon leakage receive 100 per cent free allowances according to the benchmark, while other industries receive 80 per cent free allowances according to this benchmark in 2013, gradually decreasing to 30 per cent in 2020.

Box 5. Main elements of EU Emission Trading System

The ETS now operates in 30 countries (the 27 EU Member States plus Iceland, Liechtenstein, and Norway). It covers CO_2 emissions from installations such as power stations, combustion plants, oil refineries, and iron and steel works, as well as factories making cement, glass, lime, bricks, ceramics, pulp, paper, and board.

Nitrous oxide emissions from certain processes are also covered. Between them, the installations currently in the scheme account for almost half of the EU's CO_2 emissions and 40% of its total greenhouse gas emissions. Air transport will join the scheme in 2012. The EU ETS will be further expanded to the petrochemicals, ammonia and aluminium industries, and to additional gases in 2013, when the third trading period will start

During the first trading period (2005 to 2007), Member States have auctioned only very limited quantities of carbon allowances, and also during the second trading period (2008 to 2012) the lion's share of carbon allowances is still allocated for free. From the start of the third trading period in 2013 about half of the allowances are expected to be auctioned.

The revision of the Emission Trading Directive, agreed on 17 December 2008, foresees a fundamental change from the third trading period starting in 2013. Auctioning of allowances will be the rule rather than the exception. No allowances will be allocated free of charge for electricity production, with only limited and temporary options to derogate from this rule. Sectors and subsectors found to be exposed to a significant risk of carbon leakage will receive allowances for free, based on benchmarks, but for non-exposed industries such allocations will gradually be phased out. These rules imply that as from 2013 at least half the total number of allowances is expected to be auctioned.

Free allowances will in principle be allocated based on product-specific benchmarks for each relevant product. The starting point for the benchmarks is the average of the 10% most efficient installations, in terms of greenhouse gases, in a sector and they shall take into account the most efficient techniques, substitutes, and alternative production processes.

The benchmarks will be multiplied by a historical production figure, and some other factors that are needed to ensure the respect of the annually declining total cap.

Free allowances will be product-based, not sector-based, which implies that all products of the same kind get an equal treatment in terms of carbon leakage. All relevant products will be classified as exposed to carbon leakage or not, based on the list of sectors.

Source: Copenhagen Economics based on European Commission, DG Climate Action.

Energy taxation and financing of renewable energy investments

The EU Energy Tax Directive (ETD) allows Member States to apply reduced tax rates to firms at risk of carbon leakage, though with somewhat different criteria for determining risk of leakage than the revised ETS. This is, however, proposed to be streamlined in the proposed new ETD (new approach). Moreover, in the new approach, products at risk of carbon leakage may be totally exempt from the CO_2 tax element, but for the energy tax element, reductions in tax rates may not fall below the specified minima rates, cf. Table 12

Table 12: Dealing with leakage in EU legislation

	Energy Tax Directive		EU ETS
Old approach	Energy volume based taxes Tax exemption if industry is energy intensive		Free allowances to nearly all producers
New approach	Energy content tax Tax reduction (to minimum rate) if industry is energy intensive	CO_2 tax Tax exemption if products are at risk of carbon leakage (uses same definition as EU ETS)	Free allowances, based on a benchmark to products that are at risk of carbon leakage

Source: Energy Tax Directive and EU ETS Directive.

The proposed ETD also intends to improve consistency in the coverage of emissions vis-a-vis the ETS. First, it proposes zero taxation of fossil fuels when used by installations that are covered by ETS. Second, it proposes that energy production in installations which falls below the production thresholds for inclusion in the ETS should be covered by the ETD. The minimum rates should in this case be equivalent to the expected price of ETS allowances. So to put it simply; the proposed ETD deals with both the previous problems of overlapping regulation, and the gap in regulation.

In some countries renewable energy investments are financed through an extra charge on electricity prices. In the Nordic countries where this is the case, there are provisions allowing for reduced rates for energy intensive firms. The extent of the reductions varies across the countries, where leakage exposed industries in Sweden e.g. are not obliged to buy green certificates.[46]

[46] Energimyndigheten (2010) – Åtgärder för at skydda elkunden mot höga elcertifikatpriser

4.1.2 Compensating electricity intensive industry

In the ETS directive, financial compensation to electricity intensive industry is foreseen regulated through EU State aid rules. The guiding principles for granting financial support to electricity intensive companies is currently rather vaguely defined, and is not necessarily in line with the definition of industries at risk of leakage as defined by the ETS directive. Currently, however, the Commission is revising the State aid Guidelines related to the ETS inter alia based on a consultation process which ended in May 2011.

4.1.3 Border tax adjustment mechanism and sector based CDM

In the context of global climate change negotiations, two types of anti-leakage measures have been at the forefront. They are both directed primarily at countries/regions who do not have binding emission reduction targets and who are not involved in carbon trading. The premise is that the marginal price of carbon reductions in such countries e.g. China and India, is well below producers in countries with ambitious emission reduction targets such a number of OECD countries.

The *first* such measure is the Border adjustment mechanism. This is an issue that has been widely discussed in both EU and the US especially in relation to international climate negotiations. Essentially, it boils down to domestic producers being refunded an estimated carbon tax when they export and/or while importers will have to pay a charge corresponding to the estimated carbon content of the products. The products to be levied import duties would come from countries with no binding emission reduction targets. Instead presumably, countries with firm targets would be exempt. Such measures have not yet been implemented in any country or region.

The *second* measure is the sector based CDM. It would apply to a whole, typically energy intensive, industry such as production of steel or aluminium. The sector as a whole would have to commit to reductions of emissions (and/or energy-use) within the sector beyond an agreed baseline. The definition of the baseline is inherently difficult in general, but some robustness can be defined in industries that use known best-practices and technologies which are also used world-wide. The mechanism may reduce leakage by forcing countries with non-binding countrywide targets to implement energy/CO_2 saving technologies with equivalent effect on their total production costs as for example the EU's ETS system.

4.2 Evaluating anti-leakage measures

The "anti-leakage" measures are evaluated against a list of four success criteria:

- Ability to stem leakage while maintaining incentives to reduce emissions
- Cost-benefits considerations from a public finance perspective
- Administrative feasibility in practice
- Conformity with EU internal market and WTO provisions

4.2.1 Ability to stem leakage while maintaining abatement incentives

The purpose of carbon policies is to provide incentives to reduce emissions in a cost effective manner. The purpose of "anti-leakage" measures is to stop/reduce movement of emission-intensive activities from the region with high carbon prices to regions with lower.

The first success criterion we review is the ability to score high on these two criteria. This will be achieved by providing incentives to maintain production within the high carbon price area while maintaining incentives to save CO_2 emissions.

The EU ETS post 2012 has generally been recognised as being much more targeted in dealing with carbon leakage than the ETS pre 2012. The grandfathering principle used in the period 2005 to 2012 implied that nearly all firms that were directly impacted by the scheme received free allowance whether or not they were leakage exposed. The post 2012 regime limits free allowances to industries identified at risk of leakage and is thus more targeted. Moreover, allocation of allowances is based not upon the firms' own level of actual emission (as was the case prior to 2012) but on best practice emission per unit of output within the industry.

Finally, the continued allocation of allowances is conditional upon continued production. Based on this, the ETS post 2012 provides incentives to maintain production inside the EU region while exposing the firm to full marginal incentives to save CO_2.

This is a very important issue: providing free allowances by itself does not prevent leakage: it is simply a lump sump transfer. Only by linking the continuing receipt to continuation of the emission related activity, the measure will reduce leakage.

The one caveat we note is that variations of production within some margins do not lead to reductions in the number of allowances. So there are some incentives to cash in free allowances and cut production down to the level where the amount of allowances will be reduced. But besides from this point, the system scores overall good marks on both success criteria.

Energy taxes and financing of renewable energy. Both the existing ETD and national rules for financing of renewable energy for power generation in Denmark, Norway, and Sweden provide for reduced/zero rates for energy intensive industries. Neither have specific considerations with regard to actual or potential trade intensity. The reduced/low rates should reduce carbon leakage, however at the cost of removing at the same time marginal incentives to reduce emissions. The proposed ETD from 2011 proposes to extend the principles of ETS for leakage-exposed industries to the CO_2 element of the tax, which has two advantages: more targeted support to industries actually at risk, and maintaining incentives to abatement. However, the proposed ETD will preserve the existing approach to reduced rating for the energy tax part, which in many countries will be by far the largest component of overall taxation. So the overall mark for dealing with leakage in energy taxes is middle to low for mitigating leakage and low for maintaining incentives to produce.

Border tax adjustment will ensure in theory that exported goods have no costs of carbon embodied while imported goods embody the full internal costs of carbon. However, it will also imply that exporters to regions with low carbon costs have no reason to adopt carbon saving technologies. The consequence of that depends on the importance of such regions and such products in global production and trade. Moreover, the effectiveness of such a measure depends crucially on the ability to assess the carbon content of specific goods and the origin of the "added carbon". In a globalised production chain it is relatively easy to circumvent a carbon import tariff by e.g. performing the carbon intensive part of the process in a low carbon cost country and then manufacturing the remaining product in a high carbon cost country for the purpose of exporting to a country with a carbon import tariff. In trade statistics, it is possible to assess which country that provides value added to a product in different stages.[47] However, since the "carbon added" is not necessarily equal to the value added, trade statistics serve as little help in this respect. In principle BAMs should score high on mitigating carbon leakage, lower than the newly adopted ETS in preserving incentives for carbon preservation for exporters, but higher through its ability to provide abatement incentives for importers.

A well-designed credit mechanism, such as the Clean Development Mechanism will in theory reduce carbon leakage. The basic driver is that it reduces the price of ETS allowances and hence the difference between carbon prices inside EU, the nearly monopoly buyer of CDM projects globally, and in non-Annex B countries. From a global climate policy perspective the key issue of CDM is whether it delivers "additionality".

[47] This is not without problems though, and several studies point out problems with measuring value added in trade statistics.

However, for industrial leakage more specifically the beauty of targeted sector CDM is that it may raise carbon prices in the industries that are trade exposed in developed countries. Thus well-targeted sector based CDM may offer substantial attractions for developed economies, indeed also to make it more acceptable to impose stringent climate policies.

In practice, the current CDM system has been accused of actually increasing carbon leakage. A reduction in emissions in non-Annex B country due to a CDM credit is a substitute for an emission reduction in an Annex B country, where this reduction is generally more expensive. Hence a CDM system does not reduce overall global emissions. However, the change in carbon consumption behaviour will affect carbon consumption elsewhere. While the impact of this on global emissions can both be negative and positive, studies have found that net leakage typically is positive, thus leading to an overall increase in global emissions when CDM projects are undertaken.[48]

It is worth underlining the difference between the existing project-based CDM and a new sector based CDM. Both will, for a given reduction target for the EU, reduce the allowance price by moving marginal abatement projects to regions outside ETS. Hence it will also reduce the difference between carbon prices inside and outside the EU and, all other things equal, reduce leakage pressures. But the difference between the two CDM types is that a sector CDM in addition can target leakage pressures more directly by forcing implicit carbon pricing in the targeted sectors in countries competing head-on against EU firms. Most of the CDM project in the existing system, not the least the substantial amount of CDM directed towards non-CO_2 abatement, have had no such direct effects.

Finally an important issue is how important any CDM should be in EU's abatement strategy. There is a substantial logic in suggesting that the share of the EU abatement target reduction that can be reached by CDM projects, should depend on the expected differences between carbon prices inside and outside the EU: if the expected price difference is very high without application of CDMs, then that is 1) an indication of substantial amount of low hanging options to abate outside the EU and 2) higher resulting leakage pressures on energy intensive industries.

4.2.2 Cost-benefit analysis from a public finance perspective

In addition to reviewing the effectiveness of anti-leakage measures, the question should also be asked whether it is worthwhile to prevent leakage from a national and global welfare perspective.

[48] Rosendahl & Strand (2011).

In principle, compensating energy intensive industries for the cost of carbon policies implies a loss of revenues needed to be financed by distorting tax rate changes. So in principle there is a trade-off between allocation efficiency in product markets – locating production where it is most efficiently carried out – and public finance consideration. The trade-off may over time be somewhat illusory however: for very footloose industries the revenues to be had by letting them fully pay for their allowances will disappear as they move out. Our illustrative modelling suggests that this is a realistic long term outcome if no anti-leakage provisions are included. The EU ETS system is well functioning in this perspective: keeping energy intensive inside the region in a cap-and-trade system will keep overall energy demand up and hence also overall prices of allowances. If they move out, allowance prices and hence revenue will fall.

According to some studies,[49] policies intended to reduce leakage have little effect on welfare overall – even in the countries implementing them. The explanation for this is that such policies just shift global production in certain energy-intensive goods. Although these welfare changes are small, implementing countries do benefit from adjustment policies, while most non-implementing countries would prefer no adjustment. According to these studies the *net effect* of anti-leakage policies is a slight reduction in the global cost of achieving a given level of emissions reduction.

A recent study[50] compared three anti-leakage measures – output-based rebates, import tariffs and full border adjustment –, and found full border adjustment to be the most effective tool to reduce leakage. However, the differences across anti-leakage measures and the overall appeal of such measures *decline with size of the region in which the policies are applied*. From a strict Nordic perspective, it is a reasonable conjecture that these three anti-leakage measures in practice are equivalent.

So our overall assessment is that there is a good general case from an environmental and national welfare perspective of pursuing targeted policies that contain industrial carbon leakage from the most heavily exposed industries, where revenues from emissions are in any case illusory from a long-term perspective.

The argument for using anti-leakage measures also hinges on the global as opposed to local/national/Nordic character of the environmental objective being pursued. With respect to global warming, the regional source of the emission is basically irrelevant for the size of damage caused: the relevant measure is the accumulated global emissions of CO_2. This is substantially different from addressing local or national environmental damages such as excessive noise and air pollution in con-

[49] See e.g. Böhringer et al. (2010).

[50] Böhringer et al. (2011a).

gested urban areas, or reduction of water quality from excessive use of fertilisers and pesticides. Reducing air pollution in Stockholm or achieving cleaner internal waterways in Norway produce welfare benefits that are not dependent on whether such measures are followed by similar policies in other countries.

4.2.3 Administrative feasibility in practice

Setting up and administrating anti-leakage policies are fraught with compliance costs issues and difficult trade-offs. To provide a few example: providing free allowances to nearly all firms with a compliance obligation (as done with the ETS pre 2012) is more easy to administer than defining and running programmes that define what leakage exposed industries are, and what a meaningful benchmark is for any given industry (ETS post 2012). However, providing free allowances to all instead of using revenues to reduce labour taxes lead to welfare distortions in labour and product markets.

A comprehensive approach to improve administrative feasibility is to deal with carbon leakage consistently through the different instruments that affect firms' energy costs. In other words, the criteria that determines the degree of exposure to leakage and the character of the associated treatment should depend on the specific situation of the industry and not the type of policy instrument that increase the costs of energy use. That is generally not the case to day: the EU's proposed Energy Tax Directive goes some way to improve consistent treatment in the ETS Directive and Energy Tax Directive. This will reduce compliance costs and increase efficiency for both public and private actors, but even if adopted, arbitrary differences would still prevail. Current rules for dealing with financing of renewable energy also lack common guidelines across Member States, and could thus be seen in the same perspective.

We would in particular consider the Border Tax Adjustment mechanism to be difficult to administer and apply in practice. Essentially, it assumes that at the point of entry into the importing region, it is possible to estimate both the carbon content of each product and where the production process, which leads to the emission of carbon emissions, took place. Indeed each of these estimates is fraught with major problems. The *first* issue is difficult since the carbon content of different goods vary according to the specific production process.[51] It may be possible to use e.g. EU best-practice benchmarks for carbon contents, but while this may

[51] See e.g. Nordic Council of Ministers (2010) illuminating that any given production can take place with many different technologies and different efficiency in production. Estimated carbon content of imports can be based on technologies in the country of import but this may not at all be representative of the country of exports.

not be very representative of non-EU countries[52] it lacks the ability to give incentives for producers to increase energy efficiency of their specific production process. The *second* issue is essential as the policy measure is supposed to "punish" only importation of embodied carbon emission from countries with lenient carbon policies. Imposing tariffs on embodied carbon may in general be difficult to apply in trade law since it needs to discriminate among countries. If determined to be in violation of trade law this would limit the coverage of tariffs to a fraction of the total emission embodied in trade, seriously limiting its effectiveness.[53]

4.2.4 Conformity with EU internal market and WTO provisions

The adopted revised ETS Directive and proposed ETD, if adopted, will - by definition - offer a framework for dealing with carbon leakage within EU countries that are legally consistent with EU's internal market rules.

Addressing the energy costs of *electricity intensive* users seems to be the main challenge both within Nordic countries and between EU countries in general. *Firstly*, while ETS Directive and the ETD provide compensation to e.g. energy intensive industries based on fossil fuel input, it provides no compensation to energy intensive industries based on electricity input. *Secondly*, current national compensation schemes to reduce electricity prices to energy intensive electricity users are only being regulated by the EU State aid criteria.

These criteria may not in practice be sufficient to ensure common treatment between Member States and thus give rise to competitive distortions within EU. Consequently, they may not be able to prevent carbon leakage within EU. In order to create a comprehensive EU approach to mitigate carbon leakage, we would suggest that national compensation schemes designed to compensate for higher electricity prices due to the ETS should be governed by the same principles that apply to firms directly affected by the EU ETS. A process in the Commission to adopt specific guidelines addressing such issues within the framework of EU State aid is currently ongoing. Given the importance of electricity consumption for energy intensive industries in the Nordic countries, the outcome of this propose is highly important from both a leakage and Nordic competiveness perspective.

It is possible that BAMs can be designed to be compatible with WTO rules. However, an effective application may in practice turn out to be very difficult.[54] First GATT, and later WTO, rules were designed to deal

[52] See e.g. the WTO speech by Pascal Lamy (9/12 2007),
[53] Böhringer et al. (2011b), page 4.
[54] WTO (2011).

with “treatment” of products and services at the border. BAMs, on the other hand, need to look at supply chain based determination of the size and location of the carbon related emissions from the production of the product in questions, as discussed above. Second, while WTO rules allow environmental concerns to be factored into trade policy measures, there is no easy way to compare different sets of mitigation policies, and hence the legality of any import tariff. Hence our conclusion is that BAMs may be a useful instrument to have in reserve to pressure concessions in global climate policy negotiations, but due to its difficulties of being applied effectively in practice, its credibility as a stick in such negotiations may be somewhat limited.

4.3 Overall policy recommendations

4.3.1 General principles

The study has identified a number of industries in Nordic countries with large energy costs that are competing head on in international markets with little or no scope to raise relative prices relative to key competitors. General economic welfare principles suggest that targeted measures to address industrial carbon leakage for such trade-exposed industries are well founded by both theoretical and empirical arguments. We underline in particular, as suggested above, the global character of the negative externality from CO_2 emissions: reducing emissions inside the Nordic area only to it see go up elsewhere by a corresponding amount solves no environmental problems while imposing substantial adjustment costs on the Nordic economy.

In this context, it is important that the chosen measures effectively give incentives to maintain production within the region with higher carbon prices, and at the same time preserve incentives to abatement at the margin. We note that the revised ETS Directive has gone some way to improve this balance, but that the proposed new Energy Tax Directive only goes halfway in this direction. However it is a substantial improvement of the current system.

We also recommend that the underlying criteria and instrumentation for anti-leakage measures are appropriately harmonised across the ETS Directive, the ETD as well as in the practical implementation in national legislation in Nordic and EU countries. This will reduce compliance costs, internal market distortions, and improve efficiency of CO_2 abatement.

The study has also presented results from the carbon leakage literature. One clear observations that can be drawn from this is that the smaller the region, the larger the size of carbon leakage. This has the obvious - but sometimes overlooked - implication that ambitious climate policies are not very effective if they are conducted by a small country/region.

4.3.2 *Nordic angles*

The industries with the highest risk of carbon leakage in Nordic countries are characterized by a high share of electricity in energy consumption. Neither electricity producers nor electricity-intensive consumers are compensated through free allowances, which leave electricity intensive manufactures at a serious competitive disadvantage. The possibility of compensating such firms nationally is currently guided by the EU State aid rules. Currently, these guidelines are not very adequately specified, however guidelines are currently being contemplated by the Commission. Developing a comprehensive common EU framework that is capable of offering adequate compensation to such firms should be a priority.

The key-industries in the Nordic countries at risk of leakage, except for iron and steel, are relatively less important in the large EU countries. In future definitions of the list of industries at risk of leakage, the Nordic countries should keep in mind that no political capital from large EU countries is likely to be invested to benefit industries that happen to be key Nordic leakage industries.

4.3.3 *International/global angles*

Transportation costs are a brake to carbon leakage. Increasing transportation cost by e.g. imposing carbon cost on international shipping will not only reduce emissions from shipping but also reduce carbon leakage risks. Increasing the cost of shipping will however – as is the case with border adjustment mechanisms – increase the price of Nordic imports and therefore the production cost of importing firms, thus lowering competitiveness and increasing consumer prices.

More generally, it should actively be pursued to expand the current CO_2 pricing area. While this optimally should take place within the context of UN, this increasingly becomes less realistic within an acceptable timeframe. Alternative trails to pursue could be to seek to include more countries in the EU ETS system, encouraging other bilateral CO_2 pricing areas,[55] or pursuing bilateral climate agreements e.g. as a condition in the granting of development aid or climate aid.

With Nordic countries generally in favour of an open trade environment, the perils of BAMs can hardly be overstated. Such measures may seem useful in theory and as a bargaining tool in international climate negotiations, but the measures will be difficult to apply in practice, hence undermining their effectiveness and thus their deterrence value.

---

[55] Australia for example has adopted a CO_2 pricing area of its own.

References

Antimiani et al. (2011) - Cooperative and non-cooperative solutions to carbon leakage

Babiker (2005) - Climate change policy, market structure, and carbon leakage

Bohlin (2010) - Climate Policy within an International Emission Trading System - A Swedish case

Burniaux and Martins (2000) - Carbon Emission Leakages - A General Equilibrium View

Burniaux and Truong (2002), GTAP-E, and energy-environmental version of GTAP, Technical paper no 16 www.gtap.agecon.purdue.edu/resources/tech_papers.asp

Böhringer et al. (2010) - The Global Effects of Sub global Climate Policies

Böhringer et al. (2011a) - Cost-Effective Unilateral Climate Policy Design - Size Matters. Resources for the future

Böhringer et al. (2011b) - Embodied Carbon Tariffs.

Congressional Research Service (2008), Carbon leakage and trade issues and approaches, Wikileaks 2008

Copenhagen Economics (2010) – Innovation of Energy Technologies: The Role of Taxes

Copenhagen Economics (2011) – Carbon leakage from Danish energy taxes

Climate Strategies (2007), Differentiation and dynamics of EU ETS industrial competitiveness impacts

CPB (2011a) - Trade and Climate Change

CPB (2011b) - Do border measures affect carbon leakage

Demailly and Quirion (2006), CO_2 abatement, competitiveness and leakage in the European cement industry under the EU-ETS: grandfathering vs. output-based allocation, Climate Policy, 6(1), August, pp. 93-113

Demailly and Quirion (2008a), European Emission Trading Scheme and competitiveness: A case study on the iron and steel industry, Energy Economics, 30, pp. 2009-2027

Demailly and Quirion (2008b), Leakage from Climate Policies and Border Tax Adjustment: Lessons from a Geographic Model of the Cement Industry, forthcoming in Roger Guesnerie and Henry Tulkens, editors, The Design of Climate Policy, papers from a Summer Institute held in Venice, CESifo Seminar Series, Boston: The MIT Press

Energimyndigheten (2010) – Åtgärder för at skydda elkunden mot höga elcertifikatpriser

Energy Tax Directive: 2003-96-EC, restructuring the Community Framework for the taxation of energy products and electricity

ETS Directive: Commission Decision of 24 December 2009 determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage. Document C (2009) 10251

Fisher et al. (2010), Carbon policies, competitiveness and emissions leakage: An international perspective, Resources for the future Conference Summary

Gerlagh & Kuik (2007), Carbon leakage with international technology spillovers

Gielen and Moriguchi (2002), CO_2 in the Iron and Steel Industry: an Analysis of Japanese Emission Reduction Potentials. Energy Policy, 30 : 849-863

Hoffmann (2004), Asian countries' specialization in different maritime businesses: Challenges and opportunities arising from the process of concentration in shipping. UNCTAD Working Paper

Hourcade et al (2007) - Differentiation and dynamics of EU ETS Industrial Competitiveness Impact- Climate Strategies Report

IEA (2005), Industrial Competitiveness

IEA (2008a), Climate Policy and Carbon Leakage, Impacts of the ETS on Aluminium

IEA (2008b), Issues behind competitiveness and carbon leakage

IEA (2008c), Energy efficiency indicators for public electricity production from fossil fuels, IEA information paper

IPCC (2007): Mitigation of climate change. IPCC Fourth Assessment Report. Cambridge and New York: Cambridge University Press

Kuik and Gerlagh (2003), Trade Liberalization and Carbon Leakage, the Energy Journal 24: 97-120

McKinsey and Ecofys (2006), report on international competiveness

Monjon and Quirion (2009) - Addressing leakage in the EU ETS - Results from the CASE II model

Nordic Council of Ministers (2009) – EU Emission Trading – Economical Effects of Emission Auctions

Nordic Council of Ministers (2010) – Global Carbon Footprint. Methods and import/export corrected results from the Nordic countries in global carbon footprint studies

OECD (2003) - Environmental Policy in the Steel Industry: Using Economic Instruments. NonClassifié COM/ENV/EPOC/DAFFE/FCA (2002)68/FINAL

OECD (2009) - The Economics of Climate Change Mitigation Policies and Options for Global Action Beyond 2012

Ponssard and Walker (2008) – EU emissions trading and the cement sector. A spatial competition analysis

Ritz (2009) – Carbon leakage under incomplete environmental regulation - an industry-level approach

Rosenthal & Strand (2011) – Carbon Leakage from the Clean Development Mechanism

Rutherford (2010) - Climate linked tariffs - Practical Issues

Singleton (1997), The World Textile Industry, first edition, Routledge, New York

Smale et al. (2006), The impact of CO_2

emissions trading on firm profits and market prices. Climate Policy 6(1), 31–48

TNO (2009) - Greenhouse gas efficiency of industrial activities in EU and non-EU

UN (2003), "Energy Subsidies: Lessons Learned in Assessing their Impact and Designing Policy Reform", UNEP/ETB/2003/1

University of Iceland (2009) - The effect of power-intensive industrial developments on the Icelandic economy

Walker (2006), Concrete Evidence? An Empirical Approach to Quantify the Impact of EU Emissions Trading on Cement Industry Competitiveness. School of Geography, Planning and Environmental Policy, University College Dublin. Working Paper

Warwick and Wilcoxen (2008) - Building On Kyoto: Towards A Realistic Global Climate Agreement. CAMA Working Papers 2008-13, Australian National University, Centre for Applied Macroeconomic Analysis

WTO (2007) – Speech by Pascal Lamy, 9/12 2007

WTO (2011) staff working paper, The interface between the Trade and Climate Change Regimes: scoping the issue

Sammanfattning

Prissättning av koldioxidutsläpp anses vara ett mycket effektivt verktyg för att reducera utsläpp och uppnå klimatpolitiska målsättningar. Genom att öka kostnaden för koldioxidutsläpp ges användare och producenter av fossila bränslen incitament att minska sin förbrukning och utveckla produkter och processer som medför låga koldioxidutsläpp.

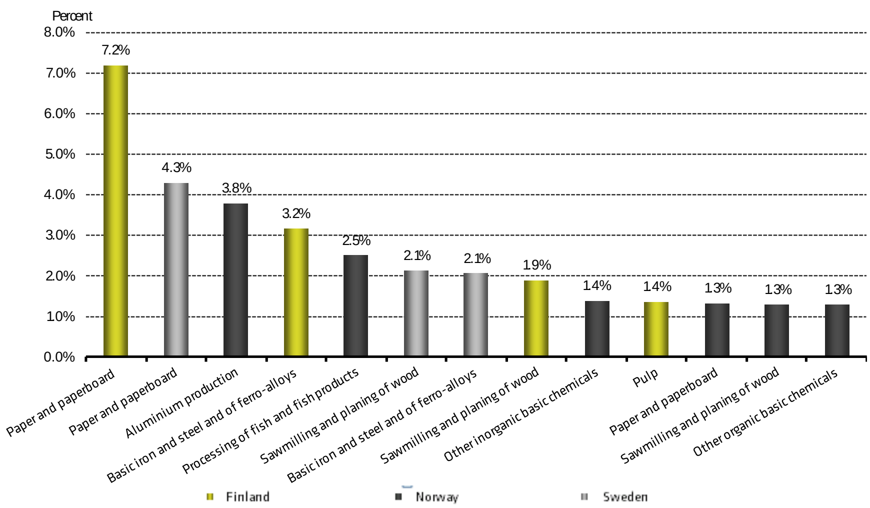
Ett problem med prissättning av koldioxid är dock att det kan leda till kolläckage. Kolläckage innebär att koldioxidutsläppen utanför den region som prisätter utsläpp ökar. På grund av relativt höga energipriser tappar företagen inom regionen i konkurrenskraft och kan därmed tvingas lägga ner produktionen eller flytta ut den utanför regionens gränser. Konsekvensen blir att utsläppen flyttas från en plats till en annan. Mängden kolläckage uttrycks som ökningen av koldioxidutsläpp utanför regionen i procent av minskningen inom regionen. Ett kolläckage på 100 procent innebär således att prissättningspolicyn är meningslös eftersom minskade utsläpp inom regionen motsvaras av en lika stor utsläppsökning utanför regionen.

I denna rapport identifieras de 25 nordiska branscher där risken för att prissättning av koldioxidutsläpp leder till kolläckage är som störst. I arbetet med att identifiera dessa har branscherna granskats utifrån flera olika faktorer som antingen ökar eller minskar risken för kolläckage. Exempel på faktorer som ökar risken är intensiv energiförbrukning, hög energieffektivitet relativt till konkurrenter utanför regionen, och/eller förekommande av processer inom produktionen som enkelt kan brytas ut och flyttas till andra länder. Intensiv energiförbrukning och möjligheten att bryta ut processer ur produktionen ökar läckagerisken på grund av att de sätter press på utflyttning av produktion. Energi effektivitet å andra sidan ökar läckarrisken genom att utsläppen per enhet ökar om produktionen flyas utomlands. Ett klassiskt exempel på en flyttbar process finns att hämta inom cementproduktionen, där den energiintensiva produktionen av klinkers enkelt kan separeras från övrig produktion och flyttas utomlands. Faktorer som verkar i den andra riktningen (sådana som minskar risken för kolläckage) karakteriseras av att de i viss mån ”skyddar” den energiintensiva industrin från konkurrens med länder som har lägre energikostnader. Exempel på sådana faktorer är höga transportkostnader, hög grad av produktdifferentiering, begränsade möjligheter till förflyttning av produktion och politiskt relaterade handelshinder (tullar, valutarisker). Läckageprocessen kan även bromsas om produktionen är kapitalintensiv, eftersom producenterna

då har en stor befintlig produktionskapacitet som kommer att användas till dess att den är förbrukad.

De nordiska industrier som bedöms vara i riskzonen för kolläckage både på kort och lång sikt finns framförallt inom sektorer med anknytning till pappers- och massaindustrin (papper och papp, sågverk och massa), järn- och stålindustrin, aluminiumindustrin, fiskerinäringen och kemikalietillverkning. Dessa riskindustrier står för mellan 1.6 procent och 14.6 procent av mervärdet i de nordiska länderna, med Danmark i botten och Finland i toppen. Sammanlagt står de för 10.2 procent av det nordiska mervärdet. De riskindustrier som är av störst ekonomisk betydelse är pappersindustrin, järn-, aluminium- och stålproduktionen.

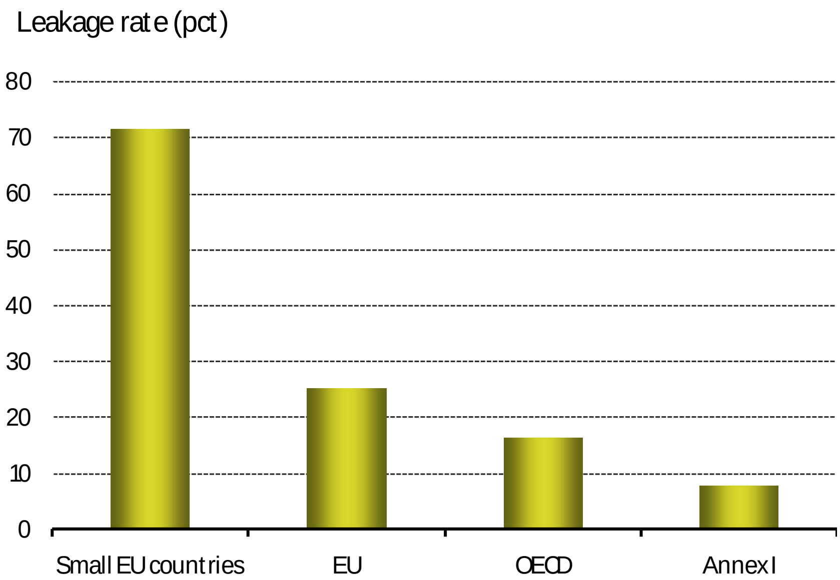
Figur: Andel av mervärdet för läckage industrier, 2007



Källa: Se figur 9 i rapporten

Det finns en stor mängd studier som behandlar problematiken med kolläckage. Uppskattningarna av kolläckagens omfattning varierar dock kraftigt. De varierande resultaten kan till stor del förklaras av studiernas olika utgångspunkter. Studier som undersöker koldioxidpolitik i mycket små regioner finner ofta högre läckagekvoter än studier som ser på större regioner. En annan orsak till de varierande resultaten är också de stora skillnaderna i studiernas metodologiska ansatser. I vår studie kommer vi att belysa denna problematik genom en genomgång av olika studiers resultat.

Figur: Koldioxidläckage beroende på regionens storlek



Källa: Se figur 10 i rapporten

Vår grundläggande slutsats är att läckagens storlek tenderar att underskattas i ett stort antal studier, framförallt på lång sikt. I många studier förbises det faktum att industrier med störst läckagerisk producerar relativt homogena produkter såsom stål, aluminium, papper och massa (vilket också är fallet i de nordiska länderna). Dessa varor säljs sedan på en global marknad till kunder över hela världen vilket innebär att prisskillnaderna är begränsade på lång sikt. Detta innebär att mycket små prisskillnader mellan de nordiska länderna och regioner utanför medför att stora delar av efterfrågan flyttas utomlands med konsekvensen att produktionen reduceras dramatiskt. Problemet blir störst på lång sikt då befintliga produktionsanläggningar är förbrukade. Studier som tar hänsyn till denna typ av långsiktiga effekter och som beaktar varornas karaktäristika finner läckagekvoter upp emot 100 procent och ännu högre för industrierna med hög läckagerisk.

I denna studie har vi inkluderat några illustrativa resultat från vår egen modell, med syftet att belysa och förklara de effekter som är förknippade med kolläckage. Utifrån dessa resultat uppskattar vi att läckagekvoter för riskindustrierna närmar sig 100 procent på kort sikt och överstiger 100 procent på lång sikt. Dessa resultat implicerar att en prissättningspolitik där koldioxidutsläpp blir väsentligt dyrare i de nordiska länderna än i övriga länder faktiskt inte kommer bidra till att reducera mängden utsläpp globalt sett, utan istället bara flytta produktionen.

Energimarknadernas funktion är av stort intresse för den nordiska diskussionen om kolläckage. Industrier som är i riskzonen för kolläckage i Norden tenderar att ta emot merparten av sin elektricitet från elnäten, medan riskföretag i andra EU länder i större utsträckning producerar sin energi själva. I förhållande till andra EU länder använder sig nordiska företag av en energimix med låga koldioxidutsläpp (vattenkraft, vindkraft, kärnkraft). Dessutom är elproducenter i nordiska länder mycket effektiva vad gäller omvandling av kol och gas till elektricitet. Detta får till följd att varje enhet energiintensiv produktion som flyttas från Norden till andra delar av EU eller andra delar av världen troligtvis kommer att åtföljas av en nettoökning av koldioxidutsläpp.

En sådan effekt skulle enbart delvis motverkas av en ökad export av överflödig ”ren” elektricitet. Detta beror på flera orsaker. Den existerande infrastrukturen kan inte facilitera en stor exportökning. Dessutom har konkurrenterna till de nordiska företagen, i nyckelindustrier såsom stålindustrin och pappersindustrin, sin produktion placerad utanför EU, vilket gör att de inte får del av marginalnyttan från överskott av grön el i norden. Ett ytterligare problem har att göra med systemet för handel med utsläppsrättigheter. Eftersom mängden av utsläppsrättigheter är fastställt till ett specifikt antal sjunker priset när efterfrågan från koldioxidläckage utsatta industrier går ner. Nettoeffekten av en prissänkning blir därmed en ökad efterfrågan och högre utsläpp från industrier vars produktion inte riskerar att skapa koldioxidläckage.

På grund av detta rekommenderar vi att de nordiska länderna tar problemet med kolläckage på allvar, både på nationell nivå och inom ramen för EU:s politiska diskussioner. I kapitel 4 utvärderar vi ett antal alternativ för hantering av läckageproblematiken både utifrån ett EU perspektiv och utifrån ett globalt perspektiv. Alternativen diskuteras från ett teoretiskt och ett praktiskt perspektiv.

Vidare belyser vi två av de områden där ett gemensamt nordiskt perspektiv skulle vara motiverat:

För det första skulle de nordiska länderna gynnas av et gemensam fokus på energiintensiva industrier. Debatten inom EU har huvudsakligen fokuserat på att erbjuda gratis utsläppsrättigheter till de energiintensiva företag som konkurrerar internationellt. Problemet är dock att det enbart är företag med egen energiproduktion som tjänar på att få dessa utsläppsrättigheter, inte företag som påverkas av utsläppspriser till följd av att de använder energi från näten. Även om detta beslut kan vara svårt att förändra just nu bör de nordiska länderna se över ramverket för det statstöd som kompenserar användare av energiintensiv elektricitet. Användningen av denna åtgärd håller just nu på att utvidgas. I översynen bör man granska huruvida politiken skapar den rätta balansen mellan användande av olika typer av energi. Det är även viktigt att säkerställa att industrier varken överkompenseras eller underkompenseras. Eftersom kompensationen till konsumenter av elektricitet kommer att ske genom nationella åtgärder och då likheterna inom de nordiska riskindustrierna är många, motiverar detta att de nordiska länderna arbetar gemensamt för att garantera en enhetlig behandling utifrån EU-regleringen. Detta är viktigt för att undvika snedvridning mellan företag i Norden.

För det andra skulle de nordiska länderna även kunna gynnas av gemensamma intressen även i en bredare global klimatpolitisk kontext. De nordiska länderna deltar alla i hög grad i den globala handeln och har alla en tradition av att stötta öppna marknader och handelsliberalisering. Några av de åtgärder som just nu föreslås för att komma tillrätta med läckageproblematiken är importtullar på produkter från regioner med svag klimatpolitik. Denna typ av åtgärder kan tyckas väl riktade för att komma tillrätta med problemen, men de kan vara mycket svåra att använda i praktiken. Dessutom rimmar de illa med den politik som förs för att främja en öppen marknad. Vi föreslår istället andra möjliga åtgärder som är mer framgångsrika i att sprida klimatpolitik på en global nivå, exempelvis utvidgande av handeln med utsläppsrätter till fler länder, eller andra typer av bilaterala överrenskommelser som behandlar problematiken med koldioxidläckage.

Appendices

Appendix A: The Carbon Leakage model

This section is concerned with a technical description of the applied carbon leakage model, a discussion of the intuition of the model, and a discussion of how specific parameter assumptions affect the resulting carbon leakage ratio.

The Copenhagen Economics Carbon Leakage model (CECLM) is a simulation model specifically designed for evaluating carbon leakage. The theoretical framework is based on Gerlagh & Kuik (2007). It is a two region model describing demand and supply of an energy intensive good and for demand of carbon-energy used as input in production and the supply thereof. The two regions are connected only by a fully integrated carbon-energy market characterised by a world price for carbon-energy. The market for energy-intensive goods are assumed to be disjoint, such that there is no effect of an increase in the product price in one region on the demand of the product from the other region. In the CECLM the theoretical framework is extended to allow for direct substitution between products, following the Armington assumption of product differentiation. As a second extension, the CECLM is set up as a multi sector model, to allow for a world market for any number of individual energy-intensive goods.

Mathematical description

The model is based on *n* different industries denoted by *i=1,…,n*. There are two different regions denoted by *l=Nordic,EU*, the Nordic countries, defined as consisting of Denmark, Sweden, Norway, and Finland, and the rest of EU27.

Each industry (*i*) of each region (*l*) produces a unique commodity. p_{il} denotes the change in the logarithm of commodity *i* in region *l*, while q_{il} is the corresponding change in the logarithm of output. Constant elasticity of demand is assumed, ε_{il}, such that demand will be given by

$$q_{il} = -\varepsilon_i p_{il} + \varepsilon_i \sigma_i \frac{\theta_{il}}{1-\theta_{il}} p_{i,-l}$$

Compared to the model of Gerlagh & Kuik, the second term of the demand equation is an extension, by which interaction between product markets in the two regions is introduced. σ_i is a share parameter, which determines to what extend a change in demand of products from region

l, say the Nordic countries, takes place through direct substitution with similar products from the EU. Finally, the cross price elasticity,

$$\varepsilon_i \sigma_i \frac{\theta_{il}}{1-\theta_{il}}$$

depend on the relative market share of region i in the world market for industry i products, denoted θ_{il}. Supply of energy intensive products is assumed to be competitive. Further, capital and labour costs per unit of production are assumed to be fixed, such that only changes in the world-market price for carbon-energy, p^{carbon}, and the regional carbon tax, τ_l , affects the product price. α_{il} is the cost-share of carbon-energy, such that the relation between the product price and the costs of carbon-energy is as follows:

$$p_{il} = \alpha_{il}(p_{carbon} + \tau_l)$$

The demand for carbon-energy of region l is defined as the sum of demand of all energy intensive industries i. Following the general convention, E_l is to be interpreted as percentages change in the demand for carbon-energy. Therefore demand for energy of each industry is weighted by their share of total emissions, λ_{il}. The demand for carbon-energy of each industry varies proportionally by production, but is also affected by the ability of firms to substitute towards other sources of input. The elasticity of substitution is denoted μ_i, such that

$$E_l = \sum_{i=1}^{n} \lambda_{il}[q_{il} + \mu_i(p_{il} - p_{carbon} - \tau_l)]$$

To close the model, a market equilibrium for carbon energy is needed. On the demand side (left), δ_l is the country share of total CO^2 emissions, by which the change in demand in each region is weighted. The change in the supply of carbon-energy depends positively of the price by an elasticity of supply, φ, such that

$$\delta_{EU}E_{EU} + \delta_{Nordic}E_{Nordic} = \varphi p_{carbon}$$

Finally carbon leakage is defined as the increase in carbon-energy in Europe relative to abatements in the Nordic countries, in response to an increase in the input tax on carbon energy τ_{Nordic}:

$$Carbon\ Leakage = \frac{\delta_{EU}E_{EU}}{\delta_{Nordic}E_{Nordic}}$$

Calibration and model intuition

In the study by Gerlagh and Kuik (2007), we find a survey of values for the behavioural parameters. We choose reasonable mean values in the model. However, we do choose to set price- and cross-price elasticities relatively high compared to other studies, to reflect the homogeneity of most of the products in question and the long term perspective. These are the chosen parameter values:

$\varepsilon_i = 4.5$
$\sigma_i = 0.9$
$\varphi = 0.3$

For the present study CECLM has been calibrated to simulate a leakage ratio for the total of those sectors that were found at the highest risk of carbon leakage in Chapter 2, the sectors listed in Table 3 and Table 5 that is.

When a tax on carbon is introduced to the industries of the Nordic countries, they are faced with the choice of incurring higher costs, and hence loose market shares, or to substitute towards other types of inputs. For example a substitution towards some type of renewable energy.

The ability to substitute towards non-carbon inputs is described by the input factor elasticity, μ_i, which in this study is assumed to take on a value of 0.1. This basically implies that firms will find it optimal to emit 1 per cent less CO_2 at any given level of production if the price of CO_2 goes up by 10 per cent.

The carbon cost share, α_{il}, of the Nordic industries is on average 6 per cent, and for the remaining EU it is 10 per cent[56]. Therefore a 10 per cent increase in the price of CO_2 will lead to an increase in the product price of 0.6 per cent.

The elasticity of demand is chosen as $\varepsilon = 4.5$, such than an increase in the product price of 0.6 as above, will lead to a 2.7 per cent drop in demand of energy intensive products produced in the Nordic countries. The total of the two first order effects are abatements of 3.7 per cent per 10 per cent increase in the carbon price differential.

It is assumed that a fixed share of 90 per cent, $\sigma = 0.9$, of the income that consumers do not spend on the now more expensive Nordic energy intensive product instead leads to increased spending on comparable goods from the remaining EU. The underlying assumption is that similar products produced abroad are on average a much better substitute than any non-energy intensive product.

The first order effect of substitution is further exaggerated by the differences in CO_2 intensities, hence λ_{il} and δ_l. Cf. Table 10 (long run net

[56] Apart from the CO_2 intensity these numbers are based on an assumed carbon energy price of 30 EUR per ton. Copenhagen Economics (2011)

list), the CO_2 intensity of EU industries is about 75 per cent higher than that of Nordic industries. Therefore, the part of abatements induced by a drop in demand is counteracted not by 90, but by 150 per cent.

The last of the behavioural parameters of the model is the elasticity of carbon energy supply, φ. It is worth noting that supply must equal demand, also in the market for carbon energy. Imagine that carbon supply is completely inelastic (φ=0). Then, no matter what policy is adopted, the total level of CO_2 emissions will remain unchanged, and hence the carbon leakage rate will be 100. The parameter is assumed to take on a value of 0.3. In other words, it takes a 1 per cent drop in the carbon price to induce a 0.3 per cent drop in the supply of carbon-energy. This rather low value is the main reason why the simulated leakage rate is not higher than is the case (102 %), despite of the first order effects as described above.

The increased demand for EU products leads to a net increase in the demand for carbon-energy, and hence an increase in the price thereof. This puts an upward pressure on the price of EU products, which serves to counteract the initial shift in demand towards EU products.

The final parameters are the market shares, θ_{il}. These are based on the same data for gross value added as used throughout the study. On average, the Nordic industries included have a market share of just 10.2 per cent. The low size of the Nordic region, relative to the whole of Europe, work to push the leakage rate up, since the smaller the region that introduces a policy to reduce emissions is, the higher the rate of leakage will be.

To explain why, imagine a world wide tax on carbon ($\theta = 1$). In that case there will be no opportunities for substitution towards products from non abating countries, the downward pressure on the gross price of carbon energy will be maximised, and hence carbon leakage will be 0.

The Carbon leakage ratio explained

The result of the calibration is an estimated leakage ratio of 102 per cent.

The key factors behind this result are, as discussed above.

First order effects:

- The assumption of a high cross price elasticity leads to a 90 per cent substitution towards foreign energy intensive goods
- The relatively low CO_2 efficiencies of EU industries makes the increased demand turn into a substantial increase in EU demand for carbon energy

Second order effects:

- Because of the low market share of Nordic industries the increase in EU demand dominates the Nordic abatements, such that there is a substantial net increase in the demand for carbon energy
- The assumption of a low supply elasticity of carbon energy and the increase in the carbon price which follows from this, works in the opposite direction of the effects described above, and hence depresses the leakage ratio towards a value of close to 100

The simulated carbon leakage ratio is not meant to simulate the result of any particular policy experiment, but rather as an illustration of the determinants of carbon leakage from a Nordic perspective. We have opted for a simple and intuitive modelling approach, in order to also highlight the effects of the exact behavioural assumptions made, as discussed in this appendix.

Appendix B: Value added of leakage exposed industries

Table 12: Share of total value added of the net list industries

NACE	Industry	Denmark	Finland	Sweden	Norway	Nordic average
2112	Manufacture of paper and paperboard	0.2%	7.2%	4.3%	1.3%	**3.7%**
271	Manufacture of basic iron and steel and of ferro-alloys	0.0%	3.2%	2.1%	0.9%	**1.7%**
201	Sawmilling and planing of wood; impregnation of wood	0.2%	1.9%	2.1%	1.3%	**1.6%**
2742	Aluminium production	0.3%	0.0%	0.3%	3.8%	**0.8%**
2111	Manufacture of pulp	0.0%	1.4%	1.1%	0.3%	**0.8%**
152	Processing and preserving of fish and fish products	0.9%	0.1%	0.1%	2.5%	**0.7%**
2413	Manufacture of other inorganic basic chemicals	0.0%	0.5%	0.3%	1.4%	**0.5%**
2414	Manufacture of other organic basic chemicals	0.0%	0.3%	0.4%	1.3%	**0.5%**
2416	Manufacture of plastics in primary forms	0.1%	0.6%	0.6%	0.4%	**0.4%**
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	0.2%	0.9%	0.2%	0.3%	**0.4%**
1571	Manufacture of prepared feeds for farm animals	0.3%	0.2%	0.0%	0.9%	**0.3%**
275	Casting of metals	0.2%	0.3%	0.2%	0.3%	**0.3%**
154	Manufacture of vegetable and animal oils and fats	0.3%	0.0%	0.2%	0.6%	**0.2%**
2744	Copper production	0.0%	0.4%	0.3%	0.0%	**0.2%**
2122	Manufacture of household and sanitary goods and of toilet requisites	0.0%	0.1%	0.5%	0.0%	**0.2%**
2441	Manufacture of basic pharmaceutical products	0.2%	0.0%	0.0%	1.1%	**0.2%**
265	Manufacture of cement, lime and plaster	0.0%	0.2%	0.1%	0.2%	**0.1%**
2745	Other non-ferrous metal production	0.0%	0.3%	0.1%	0.2%	**0.1%**
1531	Processing and preserving of potatoes	0.0%	0.1%	0.1%	0.2%	**0.1%**
2415	Manufacture of fertilizers and nitrogen compounds	0.0%	0.2%	0.0%	0.3%	**0.1%**
2412	Manufacture of dyes and pigments	0.1%	0.2%	0.0%	0.1%	**0.1%**
172	Textile weaving	0.0%	0.0%	0.1%	0.1%	**0.0%**
1583	Manufacture of sugar	0.0%	0.1%	0.0%	0.0%	**0.0%**
264	Manufacture of bricks, tiles and construction products, in baked clay	0.1%	0.0%	0.0%	0.0%	**0.0%**
1562	Manufacture of starches and starch products	0.1%	0.0%	0.0%	0.0%	**0.0%**

Note: The Nordic average is a weighted average weighted by each country's value added.

Source: Copenhagen Economics based on Eurostat data.

norden

Nordic Council of Ministers

Ved Stranden 18
DK-1061 Copenhagen K
www.norden.org

Carbon leakage from a Nordic perspective

Carbon pricing is generally considered a highly effective tool in reducing carbon emissions. Putting a price on carbon provides incentives for users and producers of fossil fuels to reduce consumption and develop low carbon products and processes. However, pursuing an ambitious climate policy can lead to carbon leakage, which refers to a situation where unilateral or regional climate change policy drives the relocation of industry investments and installations, and associated emissions, to third countries.

This report by Copenhagen Economics has been commissioned by the Nordic Council of Ministers to give an overview of the industries at risk of carbon leakage in the Nordic countries, and estimate the expected extent of carbon leakage from unilateral climate policies in the Nordic countries. The report also assesses available policy options that may reduce the risk of carbon leakage, such as exemptions from energy tax and exemptions from quota obligations under green certificate schemes. The key drivers of carbon leakage are identified, which include energy intensity, product differentiation, transportation costs and capital intensity. The analysis suggests that industries such as paper and pulp, iron and steel, aluminium, cement, pharmaceuticals, chemicals, and fertilizers are most at risk of carbon leakage in the Nordic manufacturing sector.

TemaNord 2012:502
ISBN 978-92-893-2305-5