Ministry for the Environment
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19-D-02221

s 9(2)(a) [redacted]

Dear s 9(2)(a) [redacted]

Thank you for your tweet on 27 September 2019 requesting the following under the Official Information Act 1982 (the Act):

> *"#OIA 2 @mfe_news @NZTreasury: any research on how #endcoal & other demand-side emissions policies might quicken global warming https://t.co/uIAkqpwDn6 https://t.co/6xLI9sqxsG".*

The Ministry for the Environment has identified eight documents in scope of your request, as listed in the attached table.

Seven of these documents are already publically available so have been refused under section 18(d) of the Act as the information requested is or will soon be publically available. The website addresses where you can access the public documents have been provided in the attached document schedule.

The remaining document, *Impacts of the NZ ETS on Emissions Leakage*, has been released to you in full.

You have the right to seek an investigation and review by the Office of the Ombudsman of my decision to withhold information relating to this request, in accordance with section 28(3) of the Act. The relevant details can be found on their website at: www.ombudsman.parliament.nz

Please note that due to the public interest in our work the Ministry for the Environment publishes responses to requests for official information on our website on our OIA responses page shortly after the response has been sent. If you have any queries about this, please contact our Executive Relations team at ministerials@mfe.govt.nz.

Yours sincerely

pp.

Janine Smith
Director, Climate Change

Document schedule

Document no.	Document date	Content	OIA sections applied	Notes
1	2 May 2011	Impacts of the NZ ETS on Emissions Leakage	n/a	n/a
2	August 2007	CDM Project Baseline and Leakage effects	s18(d)	https://www.sciencedirect.com/science/article/pii/S0301421507000535
3	January 2009	Trade, Competitiveness and Carbon Leakage: Challenges and Opportunities	s18(d)	https://www.chathamhouse.org/sites/default/files/public/Meetings/Meeting%20Transcripts/0109reinaud.pdf
4	1 January 2015	Carbon leakage: theory, evidence and policy design	s18(d)	http://documents.worldbank.org/curated/en/138781468001151104/Carbon-leakage-theory-evidence-and-policy-design
5	10 March 2016	Do environmental policies affect global value chains? A new Perspective on the pollution	s18(d)	https://www.oecd-ilibrary.org/economics/do-environmental-policies-affect-global-value-chains_5jm2hh7nf3wd-en

		haven hypothesis economic department working papers No. 1282		
6	June 2018	Countervailing forces: Climate targets and implications for competitiveness, leakage and innovation	s18(d)	https://www.mfe.govt.nz/publications/climate-change/countervailing-forces-climate-targets-and-implications-competitiveness
7	June 2018	Emissions pricing impact on innovation and competitiveness: A review of the international literature	s18(d)	https://www.mfe.govt.nz/node/24281
8		EU ETS non paper on carbon leakage methodology	s18(d)	http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=2ahUKEwi1upakirHlAhUx8HMBHfAPBbMQFjACegQIABAH&url=http%3A%2F%2Fcw.routledge.com%2Ftextbooks%2Feresources%2F9781849712040%2FMassai2.doc&usg=AOvVaw0k6y5CrZqMWcOUvlE452UF

covec

Final Report | April 2011

Impacts of the NZ ETS on Emissions Leakage

Prepared for

Ministry for the Environment

economics | research | forecasting | public policy

Authorship
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We help organisations to solve problems and make decisions using our core skills of economics, forecasting, research and public policy.

Contents

Executive Summary

This report has examined the concept of leakage from a theoretical perspective, using the results of modelling exercises where possible.

What is Leakage?

Leakage of greenhouse gases occurs where, as a result of emissions regulation, and particularly emissions pricing, industrial activity falls in more regulated countries and rises in less regulated countries.

Concerns over leakage can be environmental or economic. There are environmental concerns when leakage reduces the effectiveness of emission regulation, leading to a shift in the location of emissions rather than their reduction. Economic effects relate to the loss of economic activity, and this may be of concern whether production shifts to another regulated country or one that is not regulated. Despite the use of leakage language, much of the focus of concern both from a policy and analytical perspective appears to be on the loss of industrial activity per se, ie leakage language is used but the underlying concern is economic regret. Regardless, the factors used to identify firms and activities at risk of loss of output are likely to be the same as those at risk of leakage.

Predicting Leakage

Predictions of leakage are focussed on identifying industries that are most likely to reduce production as a result of a carbon price. Usually this is industries that are:

- trade-exposed—they produce an output that is widely traded and for which prices are set in international markets such that they cannot pass cost increases on; and
- emissions-intensive—an emissions price has a material impact on their costs.

To identify industries at risk of reducing output or closing, a number of governments have developed and adopted indicators and thresholds relating to both of these elements: trade and emissions intensity. New Zealand has adopted criteria relating to emissions intensity only.

Definitions of emissions intensity have tended to use relatively simple formulae based on emissions per unit of value added or revenue. Thresholds have been defined to identify those industries most at risk. These thresholds, which are reasonably arbitrary, have been set at levels that will result in a varying numbers of activities being classed as "at risk"; the European Commission has set an emissions intensity threshold at a much lower level than in Australia/NZ, potentially allowing a much larger number of industries to be eligible for free allocation.

Independent analysts have identified more complex criteria for defining risk of production loss (a proxy for leakage). However, mostly they acknowledge the difficulty of obtaining data. The simpler measures employed by governments are reasonably widely accepted, although there has been some criticism of the thresholds.

Both theory and economic modelling has demonstrated a number of channels of leakage. These include:

1. impacts on the relative competitiveness of industries, both in the short and long run when emission costs are significant relative to their revenue and/or profit;
2. changes in the relative prices of fossil fuels as a result of changes in consumption levels in carbon-regulated countries (coal prices falling relative to gas), resulting in changes in consumption in the opposite direction in other countries.

It appears that the change in energy fuel prices is a significant cause of leakage and a number of studies suggest it is the dominant cause. There are a number of implications of this, but one is that leakage will occur as a result of changes in consumption of fossil fuels both by trade-exposed and non-trade-exposed industries. To the extent that emission reductions occur through fuel switching or reductions in energy fuel demand, leakage is an inevitable consequence of any international architecture in which some countries are regulated and others are not.

A number of studies have compared the threshold criteria with the results of economic models that predict leakage and have noted that the data suggest that emissions intensity is a more useful predictor of leakage (or loss of output) than trade intensity. However, this might be because of the importance of the fossil fuel price channel as a source of leakage: it is not only trade-intensive industries that leak but it will always be emissions intensive ones.

Trade intensity and emissions intensity appear to be good indicators of industries likely to reduce output in carbon-regulated countries.

Limiting Leakage

Approaches used to reduce leakage have focussed on free allocation, although there has been some recent interest in border tax adjustments. Free allocation comes in a variety of forms. If lump sum allocation is used, this does not change marginal costs, ie firms still face a carbon price at the margin. The incentives to reduce production remain. However, if free allocation levels change with levels of activity then the marginal incentive is removed or diminished. Depending on how it is defined, output-based allocation directly addresses the leakage incentive. At the same time it removes some incentives to reduce emissions (those relating to reduced output) while retaining others (those relating to efficiency improvements or fuel switching).

While some countries price carbon and others do not, reducing the level of free allocation is likely to result in increasing risk of output loss.

1 Introduction

1.1 Background

This report examines the risks that an emissions price will lead to a reduction in industrial activity as firms shift to avoid regulatory costs. It has been commissioned to address two different audiences:

- the first review of the New Zealand Emissions Trading Scheme (NZ ETS). It assesses the likelihood of emissions leakage as a result of the introduction of the ETS and whether the removal of current limits on the cost impost of NZUs[1] would be likely to lead to increased rates of leakage;

- a wider international policy-maker audience that is considering the status of current literature on leakage and its implications for emissions trading schemes.

Because the NZ ETS has only recently been introduced, and using a reduced level of obligation that limits costs, the effects are not easily differentiated from what would have happened without its introduction. Therefore this review of impacts is undertaken at a more theoretical level and on the basis of existing literature. Our assessment starts from economic theory. This sets the scene for identifying the causes of production shifts and leakage. We then examine literature that has sought to operationalise this by developing criteria and/or thresholds for identifying activities "at risk" of leakage. We also consider literature that has examined leakage ex-post.

1.2 Dynamics of Leakage

Concern over the potential for carbon emissions leakage is an example of a wider concern over the costs of regulation, ie that countries with lower levels (and costs) of regulation will attract new investment and increased industrial activity at the expense of countries with higher levels of regulation. For other environmental issues this could lead to polluting activities being concentrated in certain locations, resulting in greater environmental and health impacts on local populations and to the loss of economic activity in the more regulated countries. For greenhouse gas emissions there is the complexity that they are global pollutants and because of the balancing mechanism of the emissions cap.

Because greenhouse gases are long-lived, they mix thoroughly in the atmosphere and the location of emissions, or of emission reductions, makes no difference to the location of impacts. Thus when emissions shift to another location, there is no offsetting environmental gain for the country that loses the economic activity.

The current global agreement for limiting greenhouse gas emissions involves a cap on emissions from developed (Annex 1) countries. Although caps have been set for individual countries also, because the Kyoto Protocol allows trades of portions of the

[1] Until the end of 2012, obligated firms are required to surrender 1 emissions unit per 2 tonnes of emissions and the emissions price is capped at $25/tonne via a government buy-out mechanism: forms can choose to surrender emission units or pay the $25.

cap, the effective emission limit is the aggregate cap of all countries that have agreed to be bound by the Kyoto Protocol. Levels of emissions in each country under the aggregate cap essentially make no difference to total emissions. Changes in emissions in one country will be met by equal and opposite changes elsewhere. However, this means that when emitting activities shift to a location outside the cap, total emissions go up. The issue is illustrated in Figure 1.

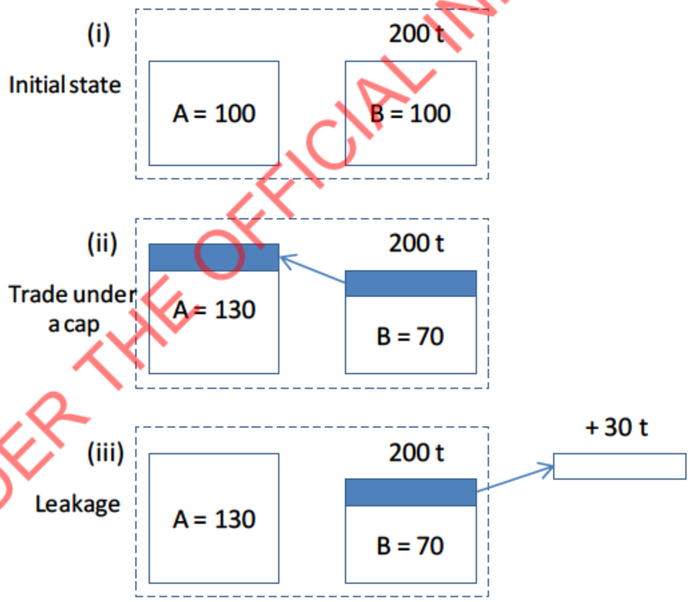
It shows:

(i) an initial situation in which 2 countries, A and B, each emit 100 tonnes. Both are under an aggregate cap on emissions;

(ii) Country A increases its emissions by 30 tonnes and does so by purchasing rights to emit from Country B, which reduces its emissions. Total emissions are held at 200 tonnes;

(iii) Industrial activity leaves Country B and increases in a country outside of the cap. However, the reduction in emissions in Country B can be balanced by an increase in Country A by the purchase of emission rights from B. Total emissions rise by 30 tonnes.

Figure 1 Impacts of leakage on global emissions



This is the basic leakage issue. There are some additional complexities to this relating to the operation of international trading markets and the restrictions on trading introduced by individual states. These are discussed in Box 1.

Box 1 Are Emissions Balanced in Practice?

One of the key assumptions in the identification of leakage is that changes in emissions are actually balanced, ie that the purchase of emission units leads to a reduction in emissions elsewhere. This is not always the case.

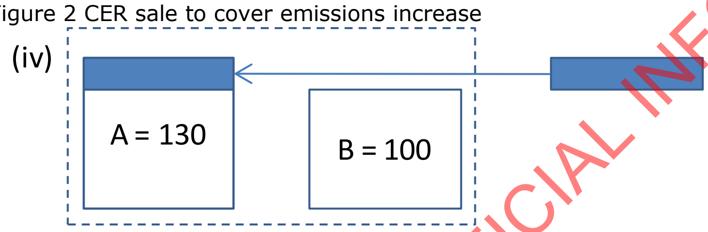
We assume that a country that increases its emissions has two options: it can purchase emission units from another Annex 1 party or it can purchase a CER from a non-Annex 1 party. Here we explore the specific case of CER purchases.

Emissions are kept in balance if emission increases in Annex 1 parties are balanced by reductions elsewhere. This happens in the case of CER purchases if increased CER consumption leads to increased supply via increased emission reductions. However, this may not be the case if:

1. there is a fixed supply of CERs and they will never be exhausted (eg through a change in international rules) or trading restrictions introduced by individual countries; or
2. the emission reductions associated with a CER are not truly additional.

In the first case, if a CER is being used currently to allow a country to increase its emissions, as is pictured in Figure 2, then the use of the CER does not lead to additional reductions in emissions. If country A is able to increase it emissions by 30 tonnes, global emission will have risen by 30 tonnes also. But this also means that, if the CER purchases are replaced by a transfer of emission units that are made available by a plant closure either in country A or country B, and a plant then increases production in a developing country (ie case iii in Figure 1), there is no net increase in global emissions and no emissions leakage.

Figure 2 CER sale to cover emissions increase



In the second case, ie limited additionality, this simply reduces the effectiveness of the CER, and means the leakage is partial. And if there is no additionality, the result is the same as described above for un-exhausted supply.

Thus the incidence of leakage depends crucially on assumptions about global markets for emission units and domestic rules on international trading. And this might explain some differences in approaches in the literature. For example, although they do not state their market assumptions, a recent paper by TNO in the Netherlands asserts that "*it is not possible to conclude that a relocation of industry from the EU to other countries will automatically result in a rise in global greenhouse gas emissions. The potential leakage depends heavily on energy provision in the country of origin and of destination and on specific production processes. Coal based countries like China have generally relatively high CO_2 intensities, but so have Poland and the Czech Republic.*"[2] They go on to assert that if relocation is away from economies that are largely coal based the carbon leakage would be zero or limited.[3] They clearly see leakage as occurring only if there is an increase in the relative emissions intensity of production. This would be the case under the CER replacement circumstances described here.

This appears to be a minority view however. But it raises an important point. **Leakage occurs only when changes in emission levels in a capped country results in an equal and opposite change in emission levels in another capped country or to a change in total supply from the CDM.** Set against this underlying condition, emissions from increased production that has shifted to an uncapped country represents an increase in global emissions.

[2] Bosch P and Kuenen J (2009) Greenhouse gas efficiency of industrial activities in EU and Non-EU. TNO report TNO-034-UT-2009-01420_RPT-ML. TNO Built Environment and Geosciences, p67
[3] Ibid, p67

1.3 Why Care About Leakage?

There are different types of concern relating to leakage. One is an environmental concern about shifts in emission sources and potential increases in global emissions. The other is an economic concern regarding the loss of economic activity. This concern can arise regardless of whether there is leakage of emissions to an unregulated country. Countries may be equally concerned if economic activity shifts to another country that regulates greenhouse gas emissions. We explore the separate issues below.

1.3.1 Environmental

The environmental concern over leakage, as shown in Figure 1, is that the emission reduction at the local level is offset by an emission increase elsewhere (under the cap) because of the exchange of emission units, and that production increases in another (unregulated) country leading to emissions that are not capped. Global emissions increase as a result.

The difference in commitments between developed and developing countries, consistent with the principle of common but differentiated responsibilities, means that developed countries must act first to reduce emissions. Shifting emissions from developed to developing countries, while consistent with developed countries bearing the initial costs, and potentially aiding the development goals of developing countries, may not be consistent with the underlying environmental objective of emission limitation commitments, ie achieving the UNFCCC Article 2 Objective.[4]

This may be a short-run perspective, developed countries taking on costs and aiding the development goals of developing countries may be consistent with a long run goal of all countries adopting quantified emission limitation commitments. However, this outcome is highly uncertain, and any causal link between leakage and an improved environmental outcome is unlikely.

1.3.2 Economic

There are a number of economic arguments for avoiding leakage that include adjustment costs and economic regrets.

Adjustment Costs

We assume that firms continue to produce when the revenues they obtain from a unit of production are greater than the additional costs of that production. If the introduction of a carbon price leads to a reduction in output, the implication is that the cost of the emission units is greater than the surplus (revenues less costs) that they would obtain from that output. For the firm, reducing output is the optimal choice; we might assume that the decision is the same at the national level also and that the nation is better off to

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[4] Article 2 reads: The ultimate objective of this Convention and any related legal instruments …. is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. ….

reduce output too. However, this may ignore some costs that apply nationally but not to the firm; specifically, it may ignore adjustment costs.

When jobs are lost, new jobs do not reappear immediately and possibly not in the same place. Similarly, capital investments may not happen immediately either. This means that there will be a loss of economic activity while adjustments take place. Depending on the length of time, this loss may be greater than the costs of plants continuing to operate at a short run loss (or the costs of mothballing). These adjustment costs are real economic costs to the nation associated with losses in production, plant closures and job losses.

Sunk Costs and Economic Regrets

In the context of the developing set of international commitments on climate change, plant closures can result in economic regrets.

A plant will continue to operate in a country if it can cover its variable operating costs and (annual) fixed costs, but the capital costs are sunk; they have no impact on the decision to continue to operate.[5] If a plant closes and production increases in developing countries, the equation changes. At some future date, assuming carbon charges are applied more widely, production from the (now closed) plant might again have been profitable. If the plant was still there, it would operate again, producing a positive surplus. However, if the plant has closed (rather than being mothballed), production will only re-commence if a new plant can cover its capital costs in addition to variable and other fixed costs. Because of this barrier, the industry may not re-invest. The level of the economic regret from such an outcome depends on the time delay, ie how long before production would again be profitable; the longer the time, the less the regret if the plant is lost.

We should note that the issue of economic regret is one that firms can weigh up as well as governments. They too can decide whether it is worthwhile experiencing short run costs, eg for operating or mothballing a plant, in order to ensure the ability to achieve positive surpluses in the future. Government intervention to avoid this might need to be justified on the basis of it having more accurate information on the likelihood of a future widespread carbon price (and that the government's information is always more weighted towards an earlier start).

It is important to note that these economic costs are of concern to governments whether there is emissions leakage or not, ie the economic regrets occur regardless of whether production shifts to an uncapped country or to another capped country.

1.4 Competitiveness Effects and Emissions Leakage – the Theory

In this section we discuss the underlying theory behind the causes of shifts in industrial production. We then turn to approaches used to predict risk of leakage.

[5] There will be some need for capital replacement costs and maintenance

1.4.1 Competitive Markets

The underlying theory is relatively simple. In a competitive market, in which all face a carbon price, it is expected that prices will be set by marginal producers (ie the highest cost producers) and that carbon prices will be passed on. Where there is elastic demand (consumption falls with an increase in price), there will be some reduction in consumption as a result. When consumption falls, some plants may no longer produce and there may be a change in which is the marginal producer setting price to a firm (or plant) with lower production costs (absent the carbon price). As a result the increase in market price will be less than the cost of carbon for all producers.

There are some risks of emissions leakage in this competitive market example. Consumption has fallen for the one product and some consumers may shift to an alternative (and inferior) good. If that good is imported, there may be emissions elsewhere. This might happen:

- within the one market, eg one building material is replaced by another; or
- across markets, because the reduced consumption of the one good increases the available income of consumers which is then spent on some other item, eg consumption of building materials is replaced by consumption of chocolate bars.

However, in general, these effects in competitive markets are exactly what a carbon price is meant to achieve. It is meant to make emissions-intensive firms and plants less competitive compared to low emission producers. And it is intended to shift consumption from one set of goods to another. So competitiveness impacts are not undesirable; the concern is over unfair competition.

1.4.2 Carbon Price Asymmetry

The picture is different when only some firms in the overall market face a carbon charge, especially when the marginal plant(s) setting price does not face that charge, eg because it is located in a different country. The ordering of plants on the supply curve may change and some that face a carbon price may lose considerable surplus. It may result in production shifts. The difference here from a market with fair competition is that prices may not change and there may be no reduction in consumption. Different producers now supply the same-sized market.

Where price is set in international markets, and goods are internationally tradable, we can think of producers as facing a perfectly elastic demand for their output. If the price of their output increases above the international price, consumption of their output will fall to zero because consumers can be assumed to have access to unlimited supplies at this international price. This is true both for domestic consumers (who can import goods at the international price) and consumers in other countries. This is where unfair competition can result in shifts in production – from countries (and firms) facing a carbon price, to countries that do not.

1.4.3 Uncompetitive Domestic Market

Another variant on the competitive market model discussed above, is where markets are uncompetitive, eg characterised by one or few producers. In these cases the level of carbon price impact on the market price of goods is likely to be much smaller than in a competitive market. In simple terms, monopolists (or oligopolists) will be raising prices as much as possible already and their ability to increase prices further is constrained by consumers' willingness to pay.[6] We note that this view is consistent with that of Smale et al[7] but at odds with the views of Cambridge Econometrics et al[8] and Dröge et al,[9] both of whom suggest that firms with a monopoly position will be better able to pass-through carbon costs.

Smale et al[10] go on to note that the more competitive the industry, the greater the cost pass-through. They use a theoretical model to note how a pure monopolist would pass through half the cost and a firm in a competitive market, close to 100%. As firms become more competitive, prices become more aligned with costs.

1.4.4 Impacts on Production Location

In this brief summary we have noted that plants compete on the basis of their marginal costs of production. This is simplistic and assumes uniform quality of output, but is broadly correct for many commodity producers most at risk of carbon cost increases.

Firms are most likely to reduce output or to close if they face a significant increase in costs relative to their current surplus (revenues from sales less costs of production) and cannot pass this cost increase on in the price of their output. Their ability to pass price on is affected by:

- the price elasticity of demand in the market as a whole; and
- the cost impacts on marginal producers that set price in the market.

Shifts in production are most likely to occur when carbon costs do not lead to a change in market prices because marginal producers do not face these costs. There are a number of potential effects of the increase in domestic supply costs. This includes:

- Plants reducing output, eg by reducing time of operation and plants elsewhere increasing output (increasing time of operation);
- Plant closures, an extreme form of output reduction; and

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[6] In uncompetitive markets we assume that producers will limit output to the point at which marginal costs of supply are equal to marginal revenue, and will raise consumption to that level of output. Marginal revenue takes account of the fact that, to increase output requires a reduction in price, and that this new lower price will apply to all output.

[7] Smale R, Hartley M, Hepburn C, Ward J and Grubb M (2006) The impact of CO_2 emissions trading on firm profits and market prices. *Climate Policy* (6): 29-46

[8] Cambridge Econometrics, Climate Strategies, Entec (2010) Assessment of the degree of carbon leakage in the light of an international agreement on climate change. A report for the Department of Energy and Climate Change, p55

[9] Dröge et al (2009) Tackling Leakage in a World of Unequal Carbon Prices. Climate Strategies. 91pp

[10] Smale R, Hartley M, Hepburn C, Ward J and Grubb M (2006) The impact of CO_2 emissions trading on firm profits and market prices. *Climate Policy* (6): 29-46

- New investment favouring locations with no carbon price.

1.4.5 Channels of Leakage

A number of authors have identified so-called channels of leakage. These are the ways in which carbon prices affect firm's costs and lead to reductions and shifts in production. The following broad channels have been identified:[11]

1. The *short-term competitiveness/operational channel*, where cost increases in carbon-constrained countries mean industrial products lose international market shares to the benefit of unconstrained competitors. This is because marginal surpluses are greater in developing countries.

2. The *investment channel*, where new investment is made in developing countries because returns on capital are greater where carbon is not priced.

3. The *fossil fuel price channel*, where reduction in global energy prices due to reduced energy demand in climate-constrained countries triggers higher energy consumption and CO_2 emissions elsewhere. This partly offsets the reduced energy consumption in the capped country.

4. *Technology and Spillover channel*—this is a dynamic effect as a price on carbon, and more importantly anticipation of a future price, will lead to innovation and a shift in R&D and investment towards low carbon technologies. This has a negative leakage effect, ie emissions are reduced in other countries not covered by an emissions price as a result of changes in technologies.

Despite the different options considered, the greatest concern has been over the industrial short-term competitiveness/operational and investment effects channel.

1.5 Other Factors in Location Decisions

The discussion from economic theory above has emphasised the cost savings that might be gained by shifting location in response to a carbon price, but the literature on company location choice notes that the factors that determine these choices can be much broader than this, encompassing market (proximity to customers), natural resource (access to resources) or efficiency (lower cost) seeking.[12] Porter, for example, notes the importance of:[13]

- factor (input) conditions, particularly specialist inputs such as skilled workers and infrastructure;
- context, including tax regimes, intellectual property rules and macroeconomic stability;

[11] Reinaud J (2008) Issues Behind Competitiveness and Carbon Leakage. Focus on Heavy Industry. IEA Information Paper; Dröge et al (2009) Tackling Leakage in a World of Unequal Carbon Prices. Climate Strategies. 91pp

[12] See Dunning JH (2009) Location and the multinational enterprise. Journal of International Business Studies, 40: 20-34.

[13] Porter ME (2008) On Competition, Updated and Expanded Edition. Harvard Business School Press

- demand conditions, including the sophistication of local customers; and
- related and supporting industries.

Because of the wide range of factors that are involved in location choice, the impact of increased cost on industry location is not certain. Much of the empirical literature suggests that there is little evidence of firms moving production to avoid environmental regulation more widely (see Section 4). However, we note some issues that are somewhat unique to New Zealand, which is the size of plants in relation to domestic demand. New Zealand Steel, for example, at approximately 50% of total production,[14] has one of the smallest domestic market shares of any steel plant in the world. The aluminium smelter has an even smaller domestic market (c10%).[15] This reduces the influence of one market reason for location here at least.

[14] BlueScope Steel Annual Report 2009/10
[15] www.riotintoalcan.com/ENG/whatweproduce/1804_nzas.asp

2 Approaches to Predicting Competitiveness Impacts and Emissions Leakage

2.1 Identifying Risk of Leakage

In previous sections we have discussed the underlying economics of leakage and the reasons for concern. In this section we discuss approaches that have been developed to predict leakage, and those industries most at risk.

The two main predictive factors have been:

- Trade exposure, ie the extent to which outputs are traded internationally and therefore the likelihood that prices are set in international markets. The argument is that, if outputs are widely traded then it is more likely that prices are set in international markets; and

- Emissions intensity, ie the materiality of cost increases as a result of the carbon price.

2.1.1 Trade Exposure

The discussion above (Section 1.4) suggested that firms are least able to pass costs on when demand is highly elastic. But this will not always lead to emissions leakage. When consumption falls as a result of a price increase, consumption may rise for some alternative product which may be less carbon intensive and/or produced locally. Leakage is more likely to occur where demand shifts to an imported carbon-intensive product or where the demand itself is in overseas markets.

A measure of trade exposure is taking account of two effects:

- High price elasticity of demand and thus the likelihood that prices cannot be passed on; and
- The risk of substitution by goods produced in other countries if price is passed on (or production is curtailed).

Demand is almost perfectly elastic when prices are set in international markets, because:

a) For firms supplying domestic markets, prices are limited by the cost of import substitutes. Domestic consumers always have the option of purchasing products from overseas at the international price, and any increase in price above this point by domestic producers can be assumed to be immediately substituted by imports.

b) For firms producing for export markets, sales prices are limited by the international price. International consumers similarly have alternative supply options at the international price.

Trade exposure is therefore generally measured by calculating the extent to which the product is internationally traded. This is generally a good indicator that prices are set in international markets, albeit that these will be tempered by transport costs.

Trade exposure also measures substitutability by international production because it explicitly assesses whether the good is traded.

There are two caveats to this: (1) market definition issues - the situation in which a good is not traded but is substituted by an alternative traded good; and (2) the concern over potential rather than actual trade.

Market Definition Issues

In theory, at least, a non-traded good may have highly elastic demand but can lead to leakage because it can be substituted by a (carbon-intensive) traded good. As an example, take liquid fuel consumption where the emissions are associated with the consumption phase far more than the production phase. The consumption is not a traded good or service, ie we cannot import a journey from City A to City B within a country. However, if the price of fuel rises because of a carbon price, it is possible that travel will be substituted by consumption of another good. For example, if marginal journeys are recreational, they might be substituted by some alternative leisure activity such as the consumption of internationally produced food or wine, or some other imported product. Here, it is the trade in the substitute that can result in leakage rather than the good itself.

Potential Trade

Risk of exposure to international price limits (trade exposure) may not be straightforward to quantify because it is the potential for trade, rather than actual trade, that limits prices currently. Thus we could imagine a tradable commodity for which there was no international trade currently and for which every country had a production plant. However, price rises in some countries only could lead to future trade, or to firms absorbing costs to avoid trade. This partly explains the New Zealand government's decisions, now enshrined in legislation, to define all activities as trade-exposed (and thus eligible for free allocation of emission units) unless: (1) there is no international trade of the output of the activity across oceans, or (2) it is not economically viable to import or export the output of the activity.[16] This second criterion effectively states that something could be trade exposed even if it is not traded currently.

Other countries have taken different stances. Reinaud suggests that there cannot be leakage without a change in trade of carbon constrained products, although this is somewhat at odds with her fossil fuel price channel.[17] She suggests that changes in trade flows might be used as an indicator. She also suggests that, over the long run, the main indicator of carbon leakage is changes in investment patterns, but she also notes the

[16] Section 161C, Climate Change Response Act 2002 (Available at: www.legislation.govt.nz)

[17] Reinaud J (2008) Issues Behind Competitiveness and Carbon Leakage. Focus on Heavy Industry. IEA Information Paper

importance of many other factors, including exchange rates, energy prices, labour and capital costs. Defining an appropriate counter-factual is of course critical.

2.1.2 Emissions Intensity

The second component of the competitiveness/leakage impact analysis is an assessment of the impacts on firm costs and/or profits. The trade exposure test assesses whether a firm can pass costs on; the emissions intensity test assesses whether the impact of not being able to pass costs on is material or not.

Below we examine some of the approaches that have been used to measure emission intensity, but we first address some generic issues in valuation and the specific metric used for emissions intensity.

Firms continue to operate and produce (at the margin) if they can cover their variable costs of production and, in the longer run, cover fixed costs and obtain a return on capital; or more importantly, cover their capital maintenance and replacement requirements. Thus the crucial analysis is whether the cost of carbon is larger than their current surplus when these other factors have been taken into account. This is not always easy to measure, especially at a sectoral level, and it raises a number of problems.

Profit

Using profit as a measure risks predicting closure of firms (or industry sectors) simply because they are not highly profitable currently, even though they may not be particularly carbon intensive based on any other intensity measure (eg proportional to costs, output or revenue). This is an issue of concern particularly because predictions of risk of leakage are used not only to predict closures but as the basis for defining industries as eligible for support policies, especially via free allocation of emission units. It is undoubtedly true that such firms are at risk of closure, but providing support to such firms may be supporting industries that are close to closure anyway, and for which leakage risks are very low in absolute terms. However, this does raise some important issues. If our concern is to avoid the adjustment costs of closure, this would apply to all firms/plants at risk of closure, not just those at risk because of a carbon price. But the crucial issue is that the carbon cost-related risks are temporary in the context of an expectation of extending commitments to all countries. Without this assumption, there is no reason to treat carbon-related cost risks differently from other factors threatening plant closures.

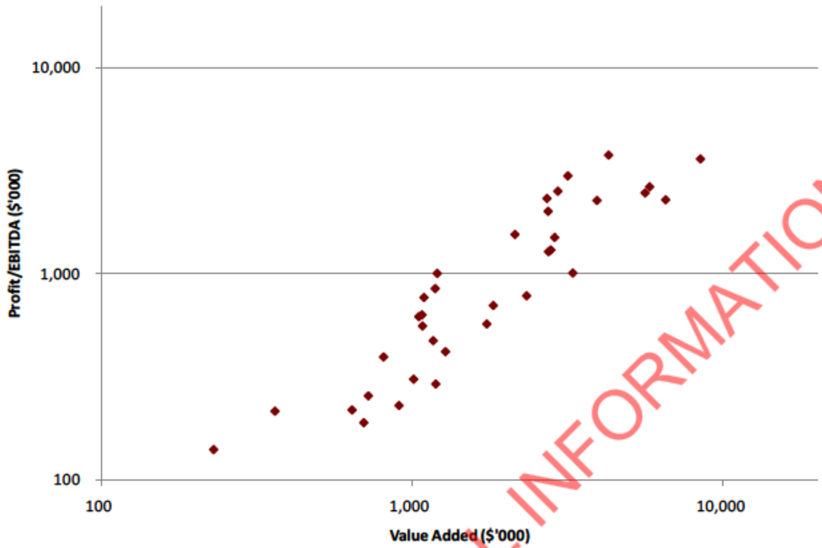
Value Added

Value added (VA) has been used as an alternative measure. It has similarities to a profit measure but includes labour costs, and this reduces the likelihood that firms will have a number close to zero. VA is a measure used in the calculation of GDP and other macro-economic calculations and can be thought of as the amount of consumption that is made possible as a result of the economic activity (as opposed to the consumption of the goods produced).[18] It is the difference between the production cost (less labour costs) and the revenue from sales of the product and is equal to the pre-tax profits (net of

[18] In aggregate, VA is a measure of GDP

depreciation) from the activity and the payments to workers and owners. In Figure 3 we show the relationship between value added and profit using New Zealand data. This is based on sectoral data collected via StatsNZ in the Annual Enterprise Survey. Value added is calculated here in a simple form as EBITDA plus labour costs. The relationship is statistically significant ($p = 5.9 \times 10^{-11}$).[19]

Figure 3 Relationship between Value Added and Profit



Source: Covec (2009) Implementing an Intensity-Based Approach to Allocation. Report to NZ Ministry for the Environment

However, measuring value added has a number of problems, as noted by the Australian government:

> *Value added (either gross or industry-specific) is a comparable concept across activities, but it can exhibit considerable variability within sectors and over time because of variations in the business cycle and the relative economic performance of entities. In addition, calculating value added requires a large amount of information on output levels, product prices, input costs and wages costs, as well as a significant number of additional items. These data would need to be agreed across all entities conducting an activity, as there are currently no widely available activity-level data on value added. Several judgments would need to be made in the collection and analysis of these data, and the collector of the data (that is, the Government) would be at a significant information disadvantage compared to industry, which could lead to disputes about final decisions. Given the significant variation in value added over the business cycle, this approach could also require the collection of emissions- and profit-related data over a number of years to avoid inadvertently benefiting some activities over others.*[20]

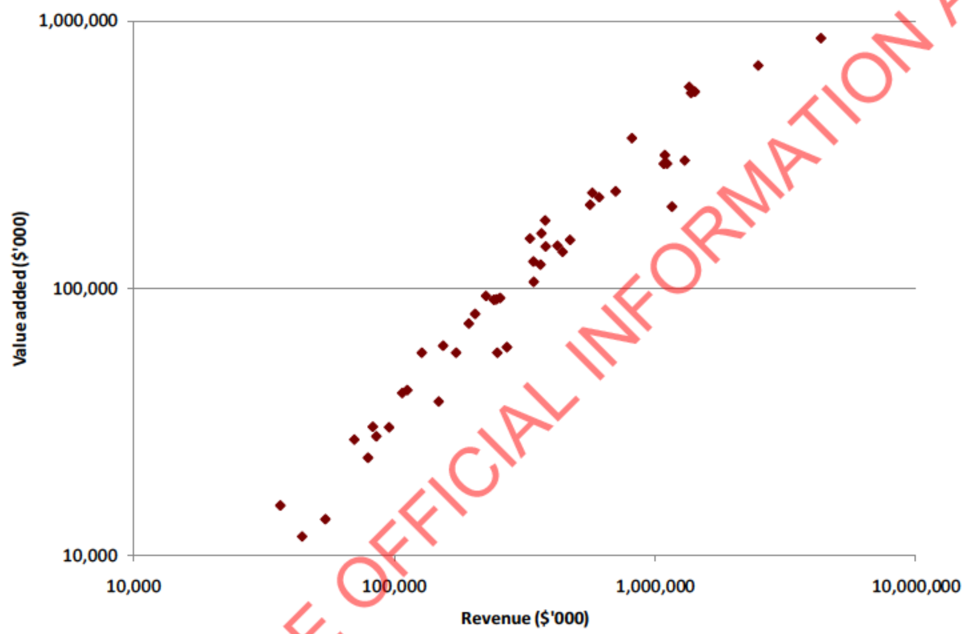
[19] This is the probability that the relationship is not significant

[20] Australian Commonwealth Department of Climate Change (2008) Carbon Pollution Reduction Scheme Green Paper. p309

Revenue

Emissions intensity measured on a revenue basis is an alternative approach. There is not necessarily a strong link between emissions intensity of revenue and risk, but it might define emissions intensive firms. Figure 4 shows the close relationship that exists between revenue and value added (using log axes); again the relationship is statistically significant. Emissions per unit of revenue are (generally) a good proxy for value added and the data are more readily available. Revenues can be estimated using third party information based on output levels and market prices.

Figure 4 Relationship between revenue and value added (input-output tables)



Source: StatsNZ; Covec analysis

However, there are occasions when the relationship breaks down. This is particularly for firms that are finishing high value products, eg an emissions intensive stage in a production process which takes a high value input to produce a high value output. Here the revenue based intensity may be low (as the revenue is high) but the value-added based intensity would be high (as VA is relatively low).

Costs

Cost-based definitions of intensity are an alternative approach. There is similarly a very close (and statistically significant) relationship between costs (revenues less value added) and value added and between revenues and costs.

It suggests that any of these measures could be used to define emissions intensity. A firm that is emissions intensive on an EBITDA basis is highly likely to be emissions intensive on a value added, revenue or cost basis. But revenue data are simplest to collect.

On cost data, the Australian government argued that the risk of carbon leakage is greater for new investments than for incumbents and, in considering these investments, it is the total returns to the project, not the ongoing operating costs that are relevant. The use of an operating cost metric would skew assistance towards capital-intensive industries and away from labour-intensive industries without effectively identifying those industries at greatest risk of carbon leakage. [21]

2.2 Predicting Impacts – Thresholds

The discussion of methods for measuring emissions intensity all assume that the more emissions intensive, the more the industry is at risk of a reduction in activity or closure. This allows an identification of relative risk, but not absolute risk. Identifying absolute risk requires either detailed industry specific evaluations or the identification of thresholds that can be applied more widely.

In this section we discuss simple criteria and thresholds used by governments; in the next section we discuss more detailed modelling approaches. Thresholds have been used by governments to set clear and fair rules that allow decisions to be made in a short time frame on multiple industries. Detailed analyses of individual industries have been used by researchers. These are useful for identifying factors that can affect industry activity (to the extent that they include multiple factors in these models) and as a check of the robustness of the government thresholds.

There is no level of cost impact that will clearly result in a reduction in activity or closure, and certainly there is no threshold that is applicable across all industries. Nevertheless, government have sought to use reasonably simple thresholds to define firms at risk.

2.2.1 EU

A sector meeting any one of the following thresholds in the European Commission's assessment is deemed to be at risk of leakage:

- increase in production costs > 5% of Gross Value Added (GVA), and extra-EU trade intensity > 10%;
- increase in production costs > 30% of GVA
- extra-EU trade intensity > 30%

These factors are calculated at a €30/t carbon price and assume no corresponding carbon control regime change in the Rest of World. Extra-EU trade intensity for any product is defined as the ratio between:

- the total value of exports to non EU countries, plus the value of imports from non-EU countries; and
- the total market size for the Community (annual turnover plus total imports).

[21] Australian Commonwealth Department of Climate Change (2008) Carbon Pollution Reduction Scheme Green Paper.

Analysts have noted that the justification for the thresholds has not been set out.[22]

There has been debate in the EU about the level at which to undertake the analysis. The current approach is to use a disaggregated analysis, starting at the 3-digit NACE level or, where appropriate and if appropriate data are available, at the 4-digit level.[23]

2.2.2 Australia

Although the Australian Carbon Pollution Reduction Scheme (CPRS) is not operational a considerable amount of work went into defining criteria and thresholds for emissions intensity, and the New Zealand ETS used a very similar approach, largely to ensure compatibility between the two systems.

An activity is considered trade exposed if it has a trade share (which is the ratio of the value of imports and exports to the value of domestic production) greater than 10 per cent in any one of the years 2004–05, 2005-06, 2006–07 or 2007–08.

Emissions intensity was assessed using the average of all entities conducting the activity. The default measure of intensity was tonnes of CO_2-e/$m of revenue. However, firms could request that the assessment be based on value added; if so, VA would apply to all entities conducting the specified activity. Value added is calculated using a proxy; it is the revenue less the cost of the major consumable inputs used in the production such as the cost of natural gas as a feedstock, energy costs and other raw and intermediate input costs.

Thresholds were set for highly and medium emissions intensive activities that would have received assistance at different levels. The thresholds were that the costs of emissions (at A$25/tonne) represent 2.5 - 5% of revenue or 7.5% - 15% of value added (Table 1). This translated into intensities of:

- Highly intensive = 2,000t CO_2-e/$m of revenue or 6,000t CO_2-e/$m of value added; and
- Medium intensive = 1,000t CO_2-e/$m of revenue or 3,000t CO_2-e/$m of value added

The VA threshold is set at 3 times the revenue threshold because VA for Australian emissions intensive industries is approx 1/3 of revenue (based on a weighted average of the value added:output ratio for emissions intensive categories in the input-output tables).

[22] Dröge S and Cooper S (2010) Tackling Leakage in a World of Unequal Carbon Prices. A study for the Greens/EFA Group
[23] Commission of the European Communities (2009) Document accompanying the Commission Decision determining a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage pursuant to Article 10a (13) of Directive 2003/87/EC Impact assessment

Table 1 Emission Intensity Thresholds

	Highly emissions intensive	Medium emissions intensive
Revenue threshold	2,000t/$M	1,000t/$M
	5% of revenue (@$25/t)	2.5% of revenue (@$25/t)
Value added threshold	6,000t/$M	3,000t/$M
	15% of value added (@$25/t)	7.5% of value added (@$25/t)

A review of the EU criteria for defining trade intensity using Australian data[24] suggested that a much larger number of industries would be made eligible than using the Australian criteria.

2.2.3 New Zealand

The New Zealand ETS has made two modifications from the other approaches:

- It has not included any formal measure of trade exposure, but assumed all are trade exposed unless it is obvious that they are not, ie it is not a traded commodity. This means that electricity generation and consumption of liquid fuels by the transport sector are both excluded.
- Emissions intensity is defined with respect to revenue only rather than value added.

The thresholds used in New Zealand were based on approaches proposed in Australia, ie it used two thresholds as defined in Table 2.

Table 2 NZ Emission Intensity Thresholds

	Highly emissions intensive	Medium emissions intensive
Revenue threshold	1,600t/$M	800t/$M
	4% of revenue (@$25/t)	2% of revenue (@$25/t)

2.2.4 US

Two proposals for ETSs in the US have set criteria for identifying energy-intensive trade-exposed industries that would be eligible for emission allowance allocation.

The Waxman-Markey Climate Change Bill (HR 2454) set thresholds of energy or greenhouse intensity being at least 5% and trade intensity at least 15%, where:[25]

- an industry's energy intensity is defined as its energy expenditures as a share of the value of its domestic production;
- an industry's greenhouse gas intensity is defined as its total greenhouse gas emissions (including indirect emissions from electricity consumption) times $20 per ton of emissions, divided by the value of the industry's domestic production; and

[24] Fisher B, Matysek A and Newton P (2009) The CPRS and the European Union Emissions Trading Scheme: The Trade Intensity of Australian Industry Sectors. BAEconomics Pty Ltd.
[25] Interagency Report (2009) The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries

- an industry's trade intensity is defined as the combined value of its exports and imports as a share of the value of its domestic production and imports.

Industries are also eligible if their energy or emissions intensity is 20%, regardless of the trade intensity.

The eligibility criteria under the Kerry-Boxer Bill (S 1733) are mostly unchanged from the Waxman-Markey Bill; the changes that have been made include changing the base year for the calculation of industry average emissions factors, and adding additional details about the way averages are calculated.[26]

2.2.5 Comparison

Table 3 compares the different approaches using a standard emission price assumption of €20/t. In other words, if the emissions price was of this level; it shows what the thresholds would translate to as an equivalent percentage of GVA or of revenue.[27] The Australian and New Zealand thresholds are broadly equivalent (as was intended), although Australia uses an additional trade intensity, whereas New Zealand does not. The EU system adopts a much lower threshold when trade intensity is taken into account also (approximately 3% of GVA compared to over 17% in Australia), which would enable a much larger set of industries to be made eligible. When emissions intensity alone is used, the threshold is slightly higher than used in Australia and New Zealand. The US approaches uses much higher thresholds, making fewer industries eligible.

Table 3 Emissions Intensity Thresholds (at €20/t) – emissions cost as % of GVA or Revenue

		Including trade intensity		Emissions intensity only	
Country	**Category**	**GVA**	**Revenue**	**GVA**	**Revenue**
EU		3.3%	1.1%	20.0%	6.7%
Australia	High	17.1%	5.7%		
	Medium	8.6%	2.9%		
NZ	High			17.5%	5.8%
	Medium			8.8%	2.9%
US		21.1%	7.0%	84.5%	28.2%

2.3 Alternative Criteria

Sectoral studies on individual industries have provided more information on the factors that lead to leakage and the sectors most at risk.
Cambridge Econometrics et al[28] (CE) suggest that, only when both a sector's trade intensity and carbon cost are moderate to high, is a sector exposed to a large risk of

[26] US EPA (2009) Economic Impacts of S. 1733: The Clean Energy Jobs and American Power Act of 2009

[27] For example, for the New Zealand high emissions intensity of 1600t/$million of revenue, a carbon price of €20/t would translate to a price n NZ$ of $36.54 or $58,458/$1 million of revenue. This is equivalent to 5.8% of revenue.

[28] Cambridge Econometrics, Climate Strategies, Entec (2010) Assessment of the degree of carbon leakage in the light of an international agreement on climate change. A report for the Department of Energy and Climate Change.

carbon leakage. They suggest that the European Commission's criteria are fairly robust, but that the thresholds may be too low and may lead to the inclusion of too many sectors. They examine and reduce a long list of factors to a short(er) consolidated list of those that are important in determining leakage:

- **Value at stake**—the cost increase from a carbon price relative to Gross Value Added (GVA). They note that, where cost increases are a significant percentage of GVA there is more risk of leakage, and where GVA is large there is more concern over that leakage.
- **External (extra-EU) trade intensity**—they base this on the EU's criteria: *the ratio between total value of exports to non EU + value of imports from non-EU and the total market size for the Community (annual turnover plus total imports) is above 30%*.
- **Sunk costs**—CE argues that the relevance of sunk costs is that an industry with high sunk costs is likely to make cautious investment choices with a long time horizon and to have limited mobility in the short run. In fact sunk costs are not the issue – almost by definition, sunk costs have no influence on future decisions. What is important is the capital intensity of future investment choices; however, the level of sunk costs may be a reasonable proxy for this.
- **International transport costs**—low international transport costs can increase the chance of import substitution with goods from countries without a carbon cost. Not noted by CE, they can also mean an exporting country has a higher underlying level of competitiveness. And, in addition, high transportation costs reduce the underlying risk of import substitution but mean that an exporter is more likely to be on the margin competitively, and more vulnerable to carbon costs.
- **Profit margins**—the ability to absorb cost increases that cannot be passed on.
- **Market segmentation and industry structure**—CE suggests that market structure affects the ability to pass through costs, largely because of the underlying competitiveness of the industry (eg the extent of market power). However, as noted above, their conclusions are that monopoly firms will be better able to pass through costs, whereas in practice they will be less likely to (see discussion in Section 1.4.3).
- **Demand growth**—if there is strong demand growth, the impacts are likely to be particularly in new investment.

However, despite concluding that these factors were important, CE identified the difficulties involved in applying weights to these issues if they were combined as a test of risk. Also, they suggested that industry structure and other issues affecting cost pass-through could not easily be measured. The study "therefore does not firmly recommend the use of additional quantitative criteria in addition to those already employed by The Commission to determine the risk of leakage".

Dröge and Cooper[29] suggest a similar list of four broad categories:

- Cost structures, including the value at stake and the degree of sunk costs;
- Pass-through ability;

[29] Dröge S and Cooper S (2010) Tackling Leakage in a World of Unequal Carbon Prices. A study for the Greens/EFA Group

- Abatement potential; and
- Institutional factors, including infrastructure quality.

They suggest that one approach is to screen the sectors individually using these or similar criteria.

TNO suggest that even emissions intensity data are difficult to ascertain. They note that "due to problems in the statistics, such as definitions and data availability on the appropriate ISIC or NACE [industry classification] level, such an approach does not approach reality and cannot be used to estimate potential leakage"[30] Nevertheless, they suggest that studies are useful in identifying the main factors that contribute to leakage, although not in predicting leakage itself. TNO suggests that fuel mix is a crucial factor, although this partly reflects their view that leakage only occurs if there is a change in the emissions intensity between the two countries, rather that the view argued here that what matters is whether production shifts from under a cap to outside a cap.

Hourcade et al[31] examine emission costs relative to GVA of the sector. They then apply thresholds of 2% indirect costs relative to GVA and 4% cumulative impact (including direct costs), noting that cost increases below this are likely to be swamped by volatility and variability of factors including exchange rates, taxation, labour costs and infrastructure provision.

ZEW[32] examines cost pass-through ability; they suggest that the ability to pass through changes in other input costs is an indication of the ability to pass through carbon costs. Thus they have examined country-specific cost shocks. They use regression analysis of cost trends to estimate proportions of costs that are passed through (Table 4). They use this to comment on the complexity of estimating pass-through. ZEW also makes the comment that leakage is likely to be a long run effect rather than short run and that the impacts will only be observable over the mid or long term.

Graichen et al[33] suggest that the combination of trade intensity indicators and value at stake indicators reveals meaningful results that allow assessment of the potential for distortion in competitiveness but that methods to assess price induced changes in demand, imports or exports, are less suitable because of their reliance on data that rarely exists, eg elasticity values.

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[30] Bosch P and Kuenen J (op cit), p3
[31] Hourcade J-C, Demailly D, Neuhoff K and Sato M (2007) Differential and Dynamics of EU ETS Industrial Competitiveness Impacts. Climate Strategies Report.
[32] Loschel A, Oberndorfer U and Alexeeva-Talebi V (2009) Understanding the competitiveness implications of future phases of EU ETS on the industrial sectors. For the Department of Business Enterprise and Regulatory Reform. Centre for European Economic Research (ZEW) Mannheim Germany
[33] Graichen V, Schumacher K, Matthes FC, Mohr L, Duscha V, Schleich J and Diekmann J (2008) Impact of the EU Emissions Trading Scheme on the Industrial competitiveness in Germany. Umweltbundesamt

Table 4 Estimates of rate of cost pass through for all sectors

Sector and Product	Energy intensity	Estimated Pass through rate	Other factors?
Refineries, UK diesel	60 %	50 % over five weeks.	Very robust results
Refineries, UK gasoline	60 %	75 %over five weeks	Very robust results
UK, LDPE	32 %	100 % over one month	Robust, but other variables used as a proxy for EUA price
UK, Ammonium Nitrate	66 %	50 % over six months	Low degree of fit.
UK, Hollow Glass	13.55 %	20-25 % over six months.	Moderate degree of fit.
UK container glass	6.13 %	No evidence	Robust
UK Ceramic goods	3.35 %	Greater than 100 %	High degree of fit.
Ceramic Bricks	12.86 %	30-40 % over 6 months	Moderate degree of fit.

Source: Loschel A, Oberndorfer U and Alexeeva-Talebi V (2009) Understanding the competitiveness implications of future phases of EU ETS on the industrial sectors. For the Department of Business Enterprise and Regulatory Reform. Centre for European Economic Research (ZEW) Mannheim Germany

In general, the literature points to complexities in assessing the likelihood of leakage but does not suggest any approach that improves on the relatively simple criteria used by governments to date.

2.4 Modelling Leakage

A number of models have been used either to analyse leakage itself or the factors that lead to leakage.

2.4.1 Macro-Economic Models

Computable General Equilibrium (CGE) and other macro-economic models are a set of models that describe the behaviour of whole economies. Often they will have little sectoral detail; their complexity lies in the way in which the model adjusts to new input information, eg changes in relative prices such as via a price on carbon. Cost increases lead to adjustments in activities within the economy (or economies) as capital, labour and resources shift from one industry or set of industries to others.

CGE models have been used to analyse leakage because they can be used either to assess reductions in output from specific industries or, when they are multi-region models, they can be used to assess reductions in one country and gains in another.

Cambridge Econometrics et al summarise the results of a series of studies largely using CGE models (Table 5). Leakage rates (the proportion of emissions from specified sectors that shift to other countries) vary between 2% and 130%. Cambridge Econometrics et al note that because of the number of input assumptions used in modelling it is not possible to assess the key determining factors. They make a number of comments on the Babiker study that predicts the very high range of impacts, noting that the author assumes that the entire energy-intensive sector is homogenous and that the entire sector shifts as a result. The other studies produce results that range from 2-20%.

Table 5 Modelled Assessments of Degree of Leakage under the Kyoto Protocol

Author	Model	Leakage rate	Comments
Babiker (2005)	Dynamic multi-region CGE model assuming: oligopolistic competition	50-130%	Leakage mainly occurring in China, India and dynamic Asian economies.
Bernstein (1999)	A multi-sector, multi-region trade model (CGE)	8-20%	
Bollen et al. (2000)	CGE model	~20%	Analyses the effects of unilateral action and permit trading
Burniaux & Truong (2002)	CGE - incorporates energy substitution	4%	
Burniaux & Martins (2000)	CGE model	2-23%	
Gerlagh Kuik	CGE model		Carbon leakage becomes negative for moderate levels of international technology spillover.
Kuik Gerlagh	Static, multi-region, multi sector, CGE		Import tariff reductions further increase the leakage rate. The main reason for leakage is the reduction in world energy prices
Light et al. (1999)	CGE model	20-21%	
Manne & Richels (1998)	Inter-temporal market equilibrium model	~20%	
McGibben (1999)	Multi-region, multi-sector CGE model	~6%	
Paltsev (2001)	Static multi-sector, multi-regional CGE	5-15%	Main contributors to leakage are the chemical and iron and steel industry.

Source: Adapted from Cambridge Econometrics, Climate Strategies, Entec (2010) Assessment of the degree of carbon leakage in the light of an international agreement on climate change. A report for the Department of Energy and Climate Change.

Some additional information can be gained from the individual studies. Burniaux and Martins[34] comment that the degree of international capital mobility does not affect leakage significantly, and that more sophisticated models than theirs support this result. It suggests that most of the capital reallocation induced by the implementation of the Kyoto Protocol would take place within Annex 1 countries rather than inducing capital flows towards non-Annex 1 countries. They found that the key factor, by far, was the supply elasticity of coal, ie that demand reduction in Annex 1 countries has a price response resulting in increased consumption elsewhere. They also found that if there is higher inter-fuel elasticity, and coal consumption shifted to other fuels, prices of these other fuels increased internationally resulting in a further shift towards coal. Their estimates of leakage rates were reasonably low, but the rates depended crucially on some of these key assumptions.

The key conclusion is that leakage appears to be widely predicted by economic models. Over-estimates appear to be based on some simplifying assumptions, eg about the ease of capital movement. The extent to which leakage occurs via price-induced demand responses in energy fuels suggests that the trade intensity criterion may not be

[34] Burniaux J-M and Martins JO (2000) Carbon Emission Leakages. A General Equilibrium View. OECD Economics Department Working Papers No 242

important. Leakage would occur from a reduction in demand for coal from a sector that is not trading.

2.4.2 Other Studies

A number of studies have examined impacts on individual sectors. Some are summarised by Julia Reinaud in a review by and for the IEA (Table 6). Leakage rates for individual sectors are substantially higher than total leakage rates in the national studies. However, Reinaud is cautious in her conclusions, noting that modelling results are ambiguous, with the results varying greatly with the models and assumptions used.

Table 6 Estimates of Leakage Rates for Individual Sectors

Study author	Sector	Region where price applies	Carbon price	Leakage impact
Gielen and Moriguchi (2002)	Iron & Steel	Japan & EU	US$11 US$21 US$42	35% (in 2020) 55% (2030) 70% (2030)
OECD (2003)	Iron & Steel	OECD-wide Unilateral	US$25 US$25	45% 60%
Demailly and Quirion (2008a)	Iron & Steel	EU-27	€20	0.5-25%
Demailly and Quirion (2006)	Cement	EU-27	€20	40%
Demailly and Quirion (2008b)	Cement	Annex B minus US, Aus, NZ	€15	20%
Ponssard and Walker (2008)	Cement	EU-27	€20 €50	70% 73%

Source: Reinaud J (2008) Issues Behind Competitiveness and Carbon Leakage. Focus on Heavy Industry. IEA Information Paper.

Cambridge Econometrics et al "stress tested" the Commission's thresholds, examining if they could quantitatively assess the degree of risk of leakage for ten selected sectors. The major task was to estimate (Armington) trade price elasticities, which are a measure of the elasticity of substitution between products of different countries (or how easy it is to substitute the produce of one country for that of another). They found that there are significant relationships between:

- domestic demand and domestic prices;
- import demand and import prices; and
- export demand and export prices for most sectors.

However, they found little evidence for cross price elasticities, for example where domestic price changes might lead to import substitution. They speculated that this was possibly the result of sufficient similarity in the production process that domestic and import prices have moved together over the historical period, or there is sufficient product heterogeneity that imports are not suitable substitutes.

The results of the framework, overall, suggest that for the sectors modelled there will be only modest leakage as a result of the carbon cost differential. Generally, their quantitative assessment found more evidence for carbon leakage in sectors which faced both high cost impacts and were heavily exposed to extra-EU trade. Sectors which had low cost and high trade exposure were not found to be at much risk of carbon leakage. Perhaps more importantly, sectors with similarly low cost which had varying trade intensities were found to be at equally low risk of carbon leakage. Manufacturing of Lime stands out as a sector exposed to high costs but low levels of trade, and in their modelling they found strong evidence of falls in domestic demand and production but only modest evidence of carbon leakage.

CE found more evidence for loss of export markets than import substitution, as indicated by the sector elasticities and noted that one potential reason for this result might be that cost differentials between EU and non-EU producers were not as great in the historical period as they might become.

Modelling impacts on EU production in the two biggest sectors, cement and steel, suggests that the overall leakage of EU emissions is unlikely to be bigger than one percent, but could be significantly higher in these sectors.[35] An equivalent analysis of the United States that has been recently published[36] reaches similar conclusions:

> *"...pricing CO2 at $15/tCO2 would lead to an average production decline of 1.3 percent across U.S. manufacturing, but also a 0.6 percent decline in consumption. This suggests only a 0.7 percent shift in production overseas. There is no statistically discernible effect on employment for the manufacturing sector as a whole … industries with energy costs exceeding 10 percent of shipment value would expect output declines of about four percent and consumption declines of three percent, suggesting a one percent shift overseas."*

There is considerable uncertainty in predicting actual leakage. Below we concentrate below on studies that have examined impacts on the factors expected to lead to leakage. This includes emissions intensities and trade intensities.

New Zealand MED Analysis

An analysis of the impacts of the NZ ETS on NZ manufacturers by staff at the Ministry of Economic Development (MED)[37, 38] was undertaken to examine the short run effects in contrast to a number of studies that had estimated the longer-run impacts on GDP. It used data collected from firm-level surveys of financial performance (revenue, costs, profit) and energy consumption. It estimated emission intensities at a disaggregated industry group level and the impacts on profit from a carbon price.

The MED study identified emissions intensity and trade intensity separately (see Figure 5). While noting that trade intensity was an imperfect indicator of the ability of a firm to

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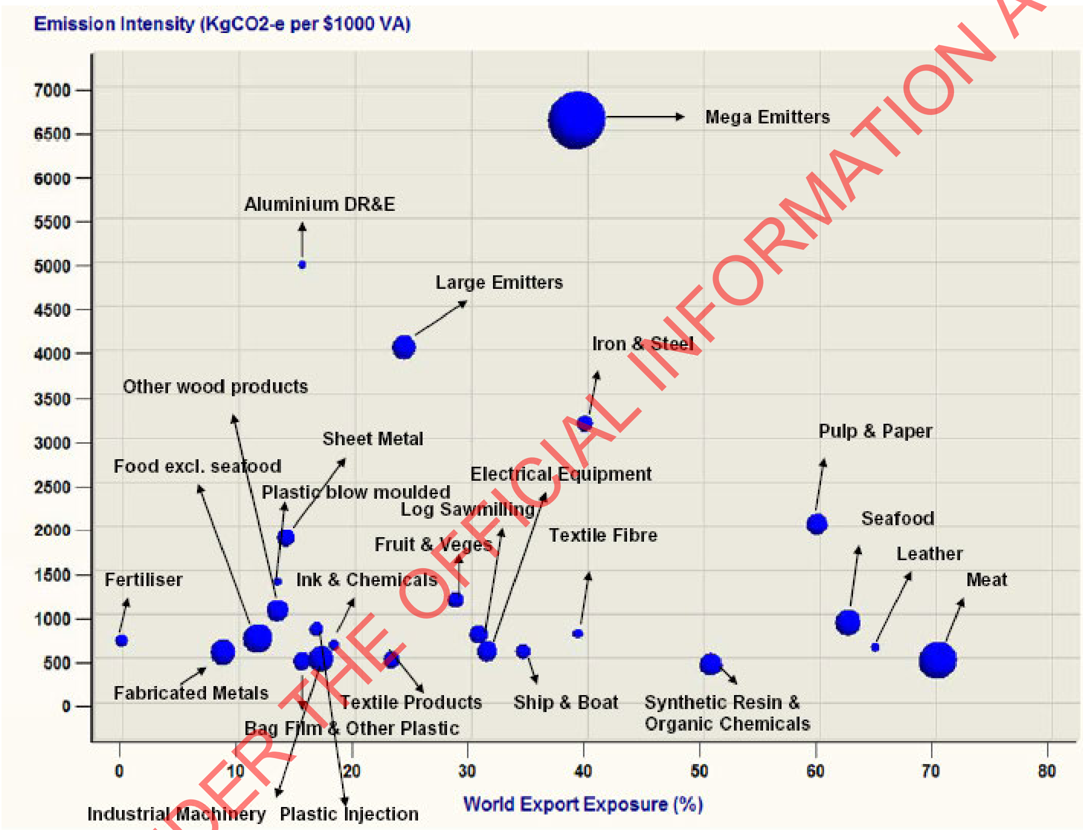
[35] Carbon Trust (2008) EU ETS impacts on profitability and trade. A sector by sector analysis.
[36] Aldy JE and Pizer WA (2009) The Competitiveness Impacts of Climate Change Mitigation Policies. Pew Center on Global Climate Change
[37] Bartleet M, Iyer K, Lawrence G, Numan-Parsons E and Stroombergen A (2010) Impact of Emissions Pricing on New Zealand Manufacturing: A Short Run Analysis. Ministry of Economic Development Occasional Paper 10/02
[38] Numan-Parsons E, Iyer K and Bartleet M (2010) The Surprising Vulnerability of New Zealand Manufacturing to CO2 Emissions Pricing: The Lessons of an International Comparison, *Economic Analysis & Policy*, 40(3): 313-325

pass costs on, they measured export trade intensity as the ratio of exports over domestic production and import trade intensity as the ratio of imports over domestic consumption. MED provides a comparison between the results of a CGE model that estimates changes in output as a result of an emissions price and the emissions and trade intensities of the individual sectors. The data show a statistically significant relationship between change in output and emissions intensity (see Figure 6) but no statistically significant relationship between output change and trade intensity. Data at a more disaggregated level show a much weaker relationship between emissions intensity and output change.

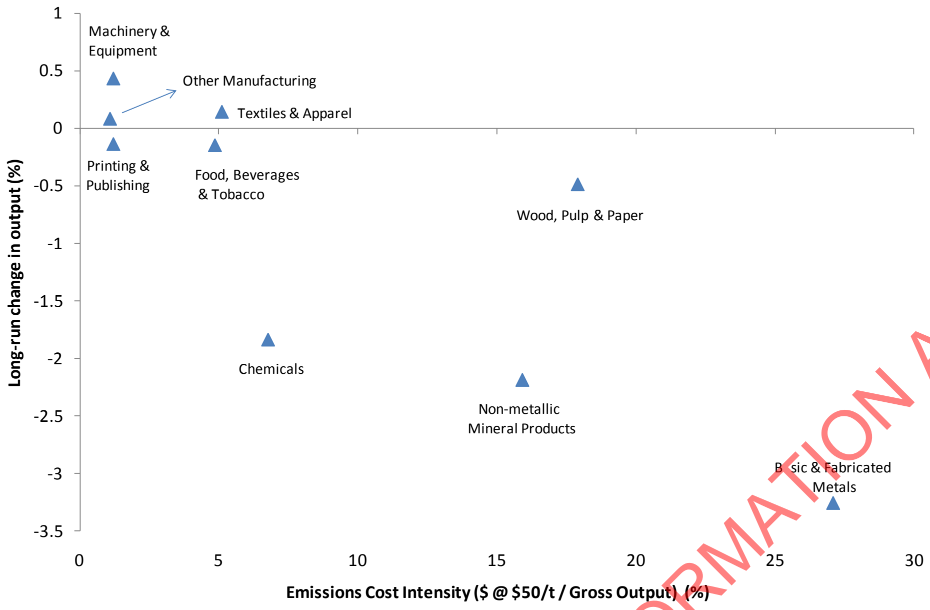
Figure 5 Emissions Intensity vs World Export Intensity



Note: bubble size = relative share of national GDP; arrows link the dot with the industry group label
Source: Bartleet M, Iyer K, Lawrence G, Numan-Parsons E and Stroombergen A (2010) Impact of Emissions Pricing on New Zealand Manufacturing: A Short Run Analysis. Ministry of Economic Development Occasional Paper 10/02

International data also show a similar result to NZ in terms of the importance of emissions intensity versus trade intensity, eg Cambridge Econometrics et al provide data on estimated changes in production under a number of scenarios, and for a number of sectors, alongside data on percentage impact on VA and trade intensity (Table 7). As for the NZ study, regression analysis suggests that the emissions intensity criterion is statistically significant, but trade intensity is not.

Figure 6 Relationship Between Emissions Intensity and Output Change in New Zealand



Source: Data from Bartleet et al (op cit)

Table 7 Production Impacts of Emissions Price

Sector	Change in EU Production (%)				Commission's criteria	
	S1	S2	S3	S3b	Cost (%)	Trade (%)
Emissions Price assumption (€/t):	30	30	40	40		
Manufacture of paper and paperboard	-0.6	-0.6	-0.8	-0.5	10.2	25.7
Manufacture of other inorganic basic chemicals	-0.9	-0.9	-1.2	-0.8	<5.0	40.6
Manufacture of plastics in primary forms	0	0.1	0.1	0.1	2.2	29.5
Manufacture of glues and gelatines	0	0	0	0	0.9	25.9
Manufacture of flat glass	-1.2	-1.2	-1.6	-0.8	7.1	21
Manufacture of glass fibres	-0.2	-0.1	-0.2	-0.2	3.4	23.5
Manufacture of ceramic tiles and flags	-15.1	-14.9	-20	-6.8	>5,<30	28.6
Manufacture of bricks, tiles and construction products, in baked clay	-0.1	-0.1	-0.1	-0.1	5.1	2.7
Manufacture of lime	-12.1	-12.1	-16.1	-5.5	65.2	2.6
Manufacture of plaster products for construction purposes	-0.8	-0.7	-1	-0.5	1.1	5.7
Manufacture of basic iron and steel and of ferro-alloys	-11.6	-11.5	-15.4	-8.5	10.6	32.3
Casting of steel	0	0	0	0	2.2	na
Manufacture of agricultural tractors	-0.2	-0.2	-0.3	-0.1	>5,<30	31.1
Manufacture of motor vehicles	0	0	0	0	0.6	28.9

Note: S1 = Reference Scenario (EU target of 20% reduction in GHG in 2020 relative to 1990, no action from other countries); S2 = Copenhagen Low (EU 20% target with other countries at lower end of Copenhagen Accord offers); S3 = Copenhagen Low, EU Stretch (30% EU target, with other countries at lower end of Copenhagen Accord offers); S3b = S3 plus 80% free allowances

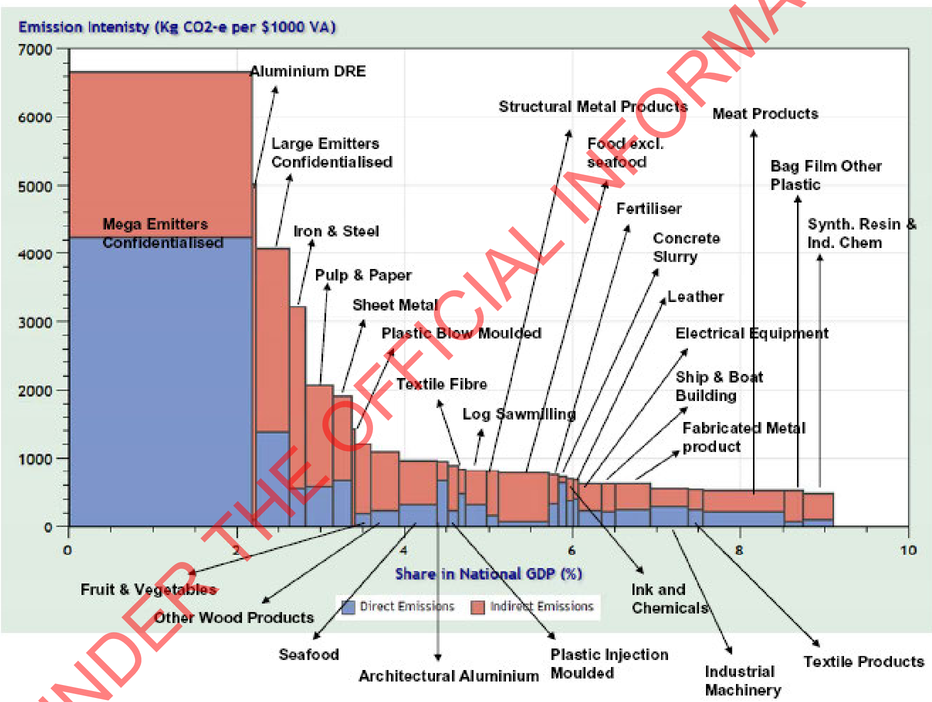
Source: Cambridge Econometrics, Climate Strategies, Entec (2010) Assessment of the degree of carbon leakage in the light of an international agreement on climate change. A report for the Department of Energy and Climate Change.

The NZ data and analysis suggest that there is some risk of output reduction at a price of $50/tonne. However, the impacts may be under-estimated by enabling partial reduction in output from industries as opposed to a trigger point that leads to plant closure.

2.5 Value at Stake

To demonstrate the quantity of GDP (total value added) that is at stake through plant closures, Bartleet et al compare the emissions intensity with contribution to total GDP (Figure 7). They provide data for activities with an emissions intensity of greater than 400kg/$1,000 VA, equivalent to 1% of VA at $25/tonne; the New Zealand thresholds are set on a revenue basis; the higher threshold used (1000t/$1000 revenue) is broadly equivalent to a threshold of 333kg/$1,000 VA.

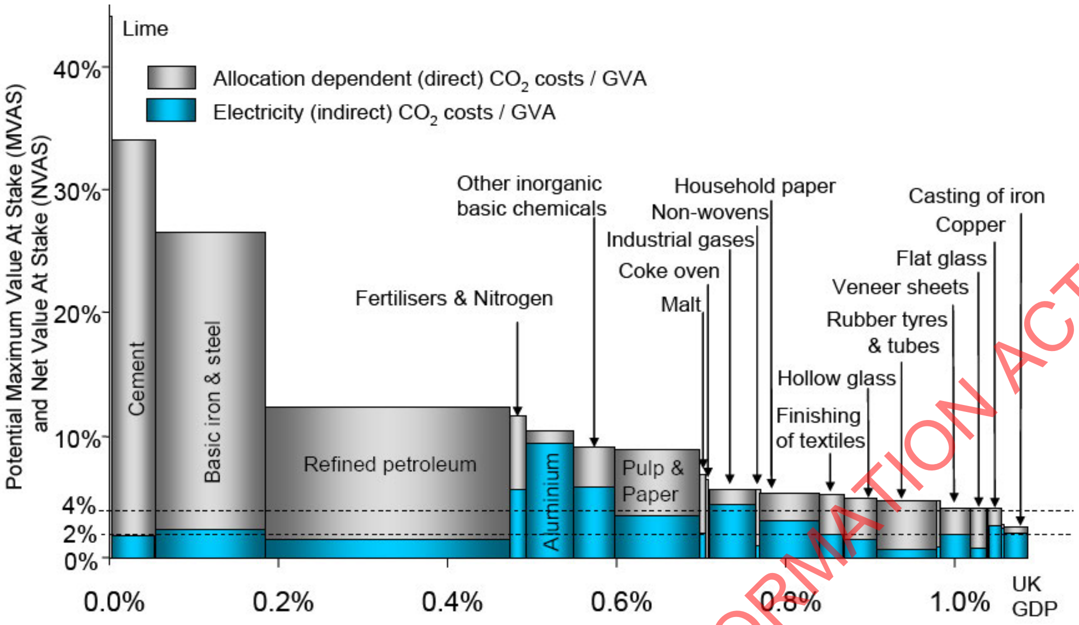
Figure 7 GDP At Stake in New Zealand



Source: Bartleet et al (op cit)

Similar analyses of impacts on value at stake have been undertaken in a number of other countries, some of which Bartleet et al refer to also. Figure 8 shows similar data for the UK, with contribution to UK GDP on the x-axis and Maximum Value Added at Stake (MVAS) on the y-axis; MVAS is defined as CO_2 cost at €20/t as a proportion of VA.

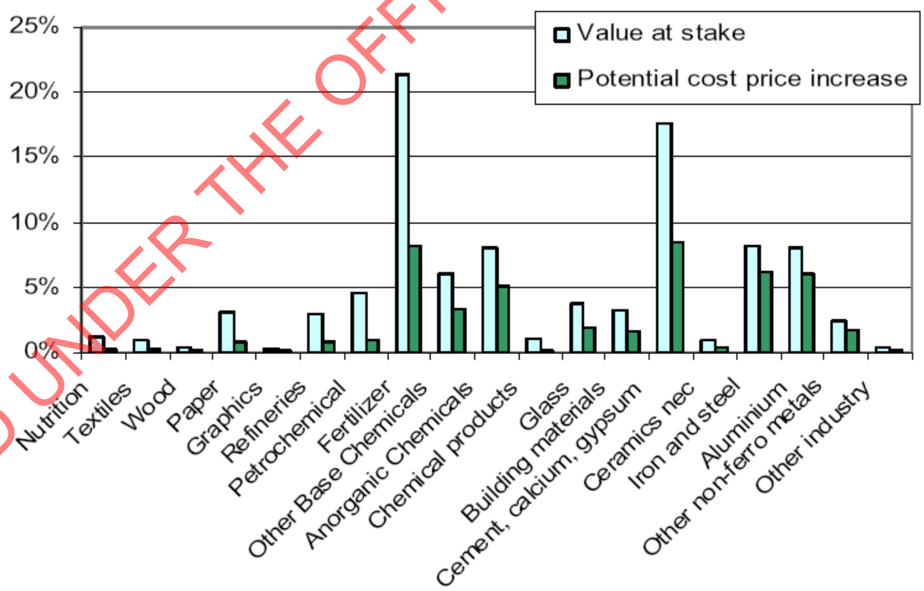
Figure 8 Value at Stake in UK



Source: Hourcade J-C, Demailly D, Neuhoff K, Sato M (2007) Differentiation and Dynamics of EU ETS Industrial Competitiveness Impacts. Climate Strategies Report

Figure 9 shows the potential cost increase for a number of different Dutch industries and the value at stake, measured as cost increase divided by value added.

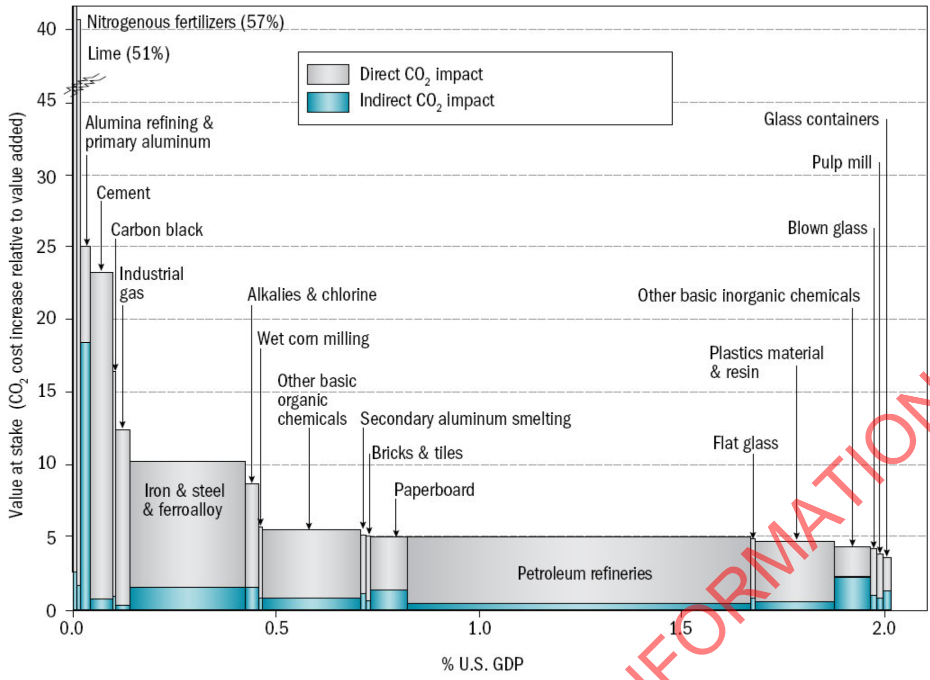
Figure 9 Value at Stake for Dutch Industry



Source: de Bruyn S, Nelissen D, Korteland M, Davidson M, Faber J and van de Vreede G (2008) Impacts on Competitiveness from EU ETS. An analysis of Dutch industry. CE Delft

Figure 10 shows US data.

Figure 10 Relative Cost-sensitivity of US Manufacturing Activities to CO_2 Pricing



Source: Houser et al in Grubb et al (2009)

Bartleet et al use the international results to compare the GDP at risk at various thresholds for defining firms at risk of closure. Using MVAS thresholds, the proportion of GDP at stake in different countries is shown in Table 8. New Zealand and Australia have a much greater proportion of GDP that is potentially at risk because they have a larger proportion of GDP contributions from sectors that are trade-exposed and emissions intensive.

Table 8 Proportion of Country GDP Potentially at Stake at Alternative Materiality Thresholds

Country	2% MVAS	6% MVAS	12% MVAS
New Zealand	8.75%	3.6%	2.8%
Australia	6.18%	1.47%	1.34%
UK	1.10%	1.05%	0.4%
Germany	2.05%	1.2%	0.55%
US[1]	2.75%	0.47%	0.4%

[1] US estimates are for % of Gross Output rather than VA

Source: Bartleet et al (op cit)

Oxera[39] analysed the effects with a model that took account of oligopoly behaviour of firms; it challenged the accepted understanding that the EU ETS would have a major negative impact on the profits of UK firms. The headline results are shown in Table 9.

[39] Oxera (2004) CO_2 emissions trading: how will it affect UK industry? Report prepared for The Carbon Trust

Table 9 Impacts of EU ETS on UK Industrial sectors (2008-12)

Sector	Increase in MC (%)	Increase in price (%)	% of MC increase passed on to customers	Change in quantity demanded (%)	Change in EBITDA (%)	Value at stake EBITDA (%)	Change in number of firms
Electricity	23	15	90	-6	63	33	0
Cement	55	14	83	-4	25	1.9	0
Newsprint	1	1	83	-1	6	0	0
Cold-rolled steel	7	3	67	-5	17	4	0
Aluminium	5	3	66	-6	-31	51	0

Note: MC = marginal cost; EBITDA = earnings before interest, tax, depreciation and amortisation
Source: Oxera (2004) CO_2 emissions trading: how will it affect UK industry? Report prepared for The Carbon Trust.

Oxera suggests that the most important factors determining the financial impact of the EU ETS are:

- The degree of non-EU competition faced by participants;
- The degree of concentration of firms in the market – the more concentrated, the more each firm will suffer (and the more competitive, the more cost-reflective prices will be);
- The price elasticity of demand for the product.

They suggest the first will be the most crucial. The results are somewhat curious because they show an increase in profit (measured as EBITDA), but this is explained by the fact that they include an assumption of free allocation in their model.

Some of the same authors used a similar model to examine the impacts on production costs and output (Table 10). The modelling suggests that firms reduce output while increasing prices to cover costs. The increased profits arise because of assumed receipt of free allowances on a historical basis; profit is higher with the increased emissions price because of the greater value of the free allowances. Aluminium smelters are outside the scheme but are affected by the increase in electricity price.

Table 10 Effects of Emissions Trading on Costs, Output and Profits from UK industry

Sector	Impact on short run marginal production cost (% increase)		Physical production output (% change)		Profit (EBITDA) (% change)	
	€15/tCO_2	€30/tCO_2	€15/tCO_2	€30/tCO_2	€15/tCO_2	€30/tCO_2
Cement	70	144	−1.2	−4.4	13	25
Newsprint	2.6	6.0	−0.2	0.68	9	15
Petroleum	0.3	0.6	−0.2	−0.7	0.4	0.6
Steel	8.0	17	−2.1	−10.6	12	18
Aluminium	4.0	13	−100	−100	−100	−100

Source: Smale R, Hartley M, Hepburn C, Ward J and Grubb M (2006) The impact of CO_2 emissions trading on firm profits and market prices. *Climate Policy* (6): 29-46

The impact is greatest on aluminium smelters. Smale et al note "There is a stark contrast between the results for the aluminium smelting sector and those for the other sectors. In short, because aluminium smelting is assumed to be a global market, even relatively small changes in cost are predicted to have significant impacts on the competitiveness of UK/EU companies relative to global companies". Despite a greater impact on marginal costs in other sectors, the impacts on production is much greater; production ceases under both emission price scenarios. Reinaud also addresses the risks of leakage from European aluminium plants but finds it difficult to draw conclusions because of the long term electricity contracts that they operate with.[40]

2.6 Sectors at Risk

There is a very long list of sectors defined at risk of leakage under the EU ETS and using the Commission's criteria.[41] Dröge et al[42] summarise a number of sector specific studies and there is considerable consistency across studies over the industries at risk.

There analysis suggests the following broad categorisation of industry sectors.

Industry sector	Average ranking	Number of ranks
Cement	2.1	7
Lime	2.6	5
Iron & steel	2.8	5
Petroleum refining	2.5	2
Alkalines & chlorine	3.0	3
Fertilizers and nitrogen	3.8	4
Aluminium	4.2	5
Pulp & paper	4.8	4
Chemicals	4.7	3

Note: Ranking is 1 = most susceptible to leakage
Source: Dröge et al (2009) Tackling Leakage in a World of Unequal Carbon Prices. Climate Strategies. 91pp

Individual studies differ in the order, eg Reinaud[43] suggests that higher leakage rates would be expected in the steel and primary aluminium sectors than in cement or electricity, because the latter are less traded. Cambridge Econometrics et al suggest that the sectors most at risk are Manufacture of Lime, Manufacture of Basic Iron and Steel and of Ferro-alloys, and Manufacture of Ceramic Tiles and Flags. Hourcade et al[44] examine costs relative to GVA of the sector. Of 159 sectors examined, they note that two sectors stand out in terms of maximum impact on costs relative to value added: Cement and Basic Iron and Steel. In 4 sectors (Aluminium, Other Inorganic Basic Chemicals, Fertilisers and Nitrogen, and Industrial Gases) the *indirect* impact from electricity price increase alone results in cost increases relative to value added in excess of 4%.

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[40] Reinaud J (2008) Climate Policy and Carbon Leakage. Impacts of the European Emissions Trading Scheme on Aluminium. IEA Information Paper
[41] 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
[42] Dröge et al (2009) Tackling Leakage in a World of Unequal Carbon Prices. Climate Strategies. 91pp
[43] Reinaud J (2008) Issues Behind Competitiveness and Carbon Leakage. Focus on Heavy Industry. IEA Information Paper
[44] Hourcade J-C, Demailly D, Neuhoff K and Sato M (2007) Differential and Dynamics of EU ETS Industrial Competitiveness Impacts. Climate Strategies Report.

Grubb et al[45] similarly note that international competitiveness impacts are limited to a small number of industry sectors. For most sectors carbon costs will be small compared to volatility in exchange rates, labour, energy and other input costs. They note that the Carbon Trust (2008a) identified six main sectors as being either significantly or plausibly of concern in the UK:

- Iron and steel
- Aluminium
- Nitrogen fertilizers
- Cement and lime
- Basic inorganic chemicals (principally chlorine and alkalines)
- Pulp and paper

Graichen et al[46] suggest that analysis of trade intensities and value at stake showed that a small number of sectors may in fact be exposed to distortions in competitiveness due to both high trade intensity and high value at stake. For Germany, these include "basic iron and steel"; "fertilizers and nitrogen compounds"; "paper and paperboard"; "aluminium and aluminium products" and "other basic inorganic chemicals".

Despite the differences in detail, there appears to be broad agreement on the key sectors.

2.7 Relative Emission Intensities

In Figure 11 we show the emissions intensity of New Zealand industries compared to emission intensities in Australia and other countries (international). Of the industries identified, it suggests that New Zealand firms are less emissions intensive on average than Australian firms in all but one industry – burnt lime, and that New Zealand firms are generally ordered somewhere between the low and high European intensity levels. For steel and aluminium these data suggest that New Zealand firms are the least emissions intensive. This suggests that, on an intensity basis, New Zealand is less at risk than firms in a number of other countries. However, the other factor that will affect New Zealand's relative position will be its distance from most international markets.

[45] Grubb M, Brewer TL, Sato M, Heilmayer R and Fazekas D (2009) Climate Policy and Industrial Competitiveness: Ten Insights from Europe on the EU Emissions Trading System.

[46] Graichen V, Schumacher K, Matthes FC, Mohr L, Duscha V, Schleich J and Diekmann J (2008) Impact of the EU Emissions Trading Scheme on the Industrial competitiveness in Germany. Umweltbundesamt

Figure 11 Relative Emission Intensities (NZ vs Other Countries) of Selected Sectors

Source: MfE; Australian Government (2011) Establishing the eligibility of emissions-intensive trade-exposed activities; EU ETS national allocation plans (http://ec.europa.eu/clima/documentation/ets/allocation_2008_en.htm)

3 Limiting Leakage

A number of approaches have been used (or studied) as means to limit leakage. Chief amongst these is free allocation and border tax adjustments. We briefly discuss these options below.

3.1 Free Allocation

3.1.1 Lump Sum Free Allocation

Lump sum allocation provides eligible firms with a number of free allowances, typically on the basis of some historical assessment of emissions or activity, or they can use industry benchmarks. Because lump sum allocations do not vary with levels of activity, they provide no disincentive to a firm to reduce its output as a result of a carbon price. As such they do not provide incentives to avoid leakage. Variants on this approach include those that update the historical data used to assess how many allowances a firm will receive, eg every five years. Such approaches limit the incentive to reduce activity.

An approach which removes the right to free allocation when a plant is closed takes away the incentive to close a plant completely (if closure can be defined) but provides no incentives short of that. It might be appropriate where the goal is to maintain capacity (eg to avoid economic regrets) as opposed to preventing leakage.

3.1.2 Updating

The activity used as the basis for allocation can be updated annually, eg if the quantity of allowances given is on the basis of tonnes of product produced, a plant could be given more allowances if it produces more, on the basis of an historical or benchmark emissions intensity. This removes the incentive to limit emissions by reducing output, and thus avoids leakage. It still retains incentives to reduce emissions through improving efficiency.

3.2 Border Tax Adjustments

Border tax adjustments have been proposed as an alternative means for addressing competitiveness concerns. These would tax imported goods on the basis of some assumed emissions rate in production in some other country, thus enabling domestic producers to increase costs to reflect their emission unit costs. Exporting firms could obtain a refund for the emissions associated with their production of those exports.

This approach raises a number of questions relating to their permissibility under GATT and WTO rules. However, a number of analysts have suggested these issues are not insurmountable.[47]

[47] de Bruyn S, Nelissen D, Korteland M, Davidson M, Faber J and van de Vreede G (2008) Impacts on Competitiveness from EU ETS. An analysis of Dutch industry. CE Delft

Cambridge Econometrics et al suggest that allocation of free allowances is more effective than border adjustment mechanisms (BAMs) applied to imports. This, they suggest, is because more leakage occurs as a result of loss of export markets than through import substitution. However, if an export subsidy approach is used also, this addresses the other side of the problem.

Border adjustment mechanisms do not address issues to do with reductions in demand for energy fuels for sectors that are not trade exposed, but neither does free allocation that does not protect these industries.

4 Ex-Ante Studies of Leakage

4.1 Other Environmental Issues

Empirical studies have sought to identify examples of leakage in practice and there has been a longer history of this in other pollution issues than for greenhouse gases. Studies have used a variety of approaches to estimate the existence of pollution havens, ie countries (or regions) that attract polluting industries through lax regulation. Research has tended to follow a methodology developed by Tobey[48] who correlated exports from polluting industries with measures of the natural endowments of countries (capital, land, labour, and natural resources) and the stringency of environmental regulation. In general he and others found little evidence of an effect, although it varies by industry and is more observable at a disaggregated level.

Van Beers and van den Bergh[49], building on Tobey's methodology, found the somewhat surprising result that environmental regulation led to increased exports, ie that it attracted industry. They suggest that variables are missing in the regression equations and speculate that countries may be employing complementary measures, such as export subsidies. This would be consistent with a view that countries that intervened more on environmental policy would be more likely to interventionist in a wider sense.

Cole and Elliot[50] found that, using Tobey's approach, the environmental regulations were not statistically significant determinants of exports of polluting industries. Rather other factors were more important. They found that iron & steel exports were highest in capital abundant countries, and that exports of non-ferrous metals (aluminium) and pulp & paper were highest in countries with natural resource (minerals, forests) endowments. They used a study methodology which measured changes in the shares of trade that were intra and inter-industry trade; they found that environmental regulation influenced the composition of trade.

Dean et al[51] examined specific examples of equity joint ventures in China. They found that investment went into provinces with high concentrations of foreign investment, skilled workers, concentrations of foreign firms and special incentives. Relatively weak environmental levies attracted joint ventures with partners from certain countries only: Hong Kong, Macao, Taiwan and other Southeast Asian countries; partners from developed countries (US, UK, Japan) tended to invest in provinces with stringent

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48 Tobey J (1990) The effects of Domestic Environmental Policies on Patterns of World Trade: An Empirical Test *Kyklos* 43(2): 191-209. In Quiroga M, Sterner T and Persson M (2007) Have Countries with Lax Environmental Regulations a Comparative Advantage in Polluting Industries? Resources for the Future Discussion Paper DP 07-08

49 Van Beers C and van den Bergh JCJM (2000) The impact of Environmental Policy on Foreign Trade. Tinbergen Institute Discussion Paper TI 2000-169/3

50 Cole MA and Elliot RJR (2003) Do Environmental Regulations Influence Trade Patterns? Testing Old and New Trade Theories. Economics Discussion Paper 0310, School of Social Sciences, University of Manchester

51 Dean JM, Lovely ME and Wang H (2004) Foreign Direct Investment and Pollution Havens: Evaluating the Evidence from China. US International Trade Commission Office of Economics Working Paper 2004-01-B

environmental levies. They suggest that this reflects differences in technology between the different countries.

A recent Resources for the Future study[52] summarises many of the studies, noting that the studies show no real evidence of a pollution-haven effect. They add additional dimensions to the analysis, including assessing the ways in which environmental regulations are applied in practice to provide a fuller analysis of regulatory costs; they also examine effects at greater levels of disaggregation. They find some evidence for a pollution-haven effect in non-metallic minerals (eg cement and lime, ceramics, glass) and iron and steel.

Thus we find little ex-post experience from other issues to support the leakage hypothesis. This raises the question of whether leakage associated with carbon or greenhouse gas regulation is different.

4.2 Implications for Greenhouse Gas Leakage

The pollution studies noted above have addressed the incidence of pollution havens. The implications have been that there are a number of other factors that are significant in the choice of location, including local institutional factors and infrastructure.

One of the most significant differences is the scale of potential costs. Many pollution control devices are installed in the form of additional capital cost items at the time of construction, with additional relatively low running costs thereafter. One of the highest cost techniques is flue gas desulphurisation (FGD) for SO_2 control. Taking account of capital and running costs, this is estimated to cost approximately US$10 per ton of coal combusted (NZ$15/tonne). In comparison a carbon cost at $25/tonne is equivalent to close to NZ$50/tonne of coal. Other pollution control devices will be considerably less than FGD. The financial incentives to avoid CO_2 costs are likely to be considerably higher.

In addition, plants can be low-polluting in every other respect but still emit large quantities of CO_2. As a result there may be no adverse implication for a developed country firm's corporate responsibility credentials. To the extent that this pressure is a constraint, it does not apply nearly as readily to CO_2 emissions.

The experience from other issues is of note largely for clarifying the range of issues that determine location decisions, but the scale of possible financial costs associated with CO_2 emissions means the risk of leakage is that much greater.

[52] Quiroga M, Sterner T and Persson M (2007) Have Countries with Lax Environmental Regulations a Comparative Advantage in Polluting Industries? Resources for the Future Discussion Paper DP 07-08

5 Conclusions

This report has aimed to provide information that would address the question: are industrial sectors at risk of leakage if measures introduced to limit emission costs are removed? The answer appears to be a qualified yes.

Both theory and economic modelling has demonstrated a number of channels of leakage. These include:

1. impacts on the relative competitiveness of industries, both in the short and long run when emission costs are significant relative to their revenue and/or profit;
2. changes in the relative prices of fossil fuels as a result of changes in consumption levels in carbon-regulated countries (coal prices falling relative to gas), resulting in changes in consumption in the opposite direction in other countries.

It appears that the change in energy fuel prices is a significant cause of leakage and a number of studies suggest it is the dominant cause. There are a number of implications of this, but one is that leakage will occur as a result of changes in consumption of fossil fuels both by trade-exposed and non-trade-exposed industries. To the extent that emission reductions occur through fuel switching or reductions in energy fuel demand, leakage is an inevitable consequence of any international architecture in which some countries are regulated and others are not.

This brings into focus the key policy concerns over leakage, and specifically whether the major concern is over the (counter-balancing) increase in emissions in non-Annex 1 countries or the loss of industrial activity from Annex 1 countries. Despite the use of leakage language, much of the focus of concern both from a policy and analytical perspective appears to be on the loss of industrial activity per se, ie leakage language is used but the underlying concern is economic regret.

Regardless, the factors used to identify firms and activities at risk of loss of output are likely to be the same as those at risk of leakage. We note that a number of studies have compared the threshold criteria with the results of General Equilibrium modelling exercises that predict leakage and that the data suggest that trade intensity is not a useful predictor of leakage (or loss of output), whereas emissions intensity is. However, this might be because of the importance of the fossil fuel price channel as a source of leakage, it is not only trade-intensive industries that leak but it will always be emissions intensive ones. However, trade intensity and emissions intensity remain good indicators of industries likely to reduce output in carbon-regulated countries.

Approaches used to reduce leakage have focussed on free allocation, although there has been some recent interest in border tax adjustments. Free allocation comes in a variety of forms. If lump sum allocation is used, this does not change marginal costs, ie firms still face a carbon price at the margin. The incentives to reduce production remain. However, if free allocation levels change with levels of activity then the marginal incentive is removed or diminished. Depending on how it is defined, output-based allocation directly addresses the leakage incentive. At the same time it removes some incentives to reduce emissions (those relating to reduced output) while retaining others (those relating to efficiency improvements or fuel switching).

The implication of this for consideration of output loss is that removal of these instruments is likely to result in increasing risk of output loss while some countries price carbon and others do not.