CLIMATE CHANGE
16/2018

Forms and Channels of Carbon Leakage

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Umwelt Bundesamt

CLIMATE CHANGE 16/2018

Environmental Research of the
Federal Ministry for the
Environment, Nature Conservation
and Nuclear Safety

Research Report within Project No. (FKZ) 3715 43 5010

Forms and Channels of Carbon Leakage

by

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On behalf of the German Environment Agency

Imprint

Publisher:
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Study performed by:
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Pfalzburger Straße 43/44
10717 Berlin

Study completed in:
February 2018

Edited by:
Section E 2.3 Economic Aspects of Emissions Trading, Monitoring, Evaluation
Alexandra Zirkel, Frank Gagelmann

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4359

Dessau-Roßlau, June 2018

Abstract

The notion of carbon leakage has received much attention in recent years, both as a subject of research, and even more as an issue in the political debate on climate policy. As a consequence, there are different understandings of what constitutes carbon leakage, and different definitions. At the core, carbon leakage always looks at undesirable consequences of a situation where different jurisdictions pursue climate policies at different ambition levels; yet the different debates differ as to which consequences they consider, and how they are assumed to come about. This paper structures and summarises some of the debates around carbon leakage. To do this, it distinguishes different strands of the debate. These have viewed carbon leakage alternatively as a problem for the effectiveness of unilateral (or non-harmonised) climate policy, for its economic efficiency in terms of reducing emissions at least cost, for the competitiveness of businesses in the jurisdiction with more ambitious regulation, and as a possible contradiction for the emerging discussion on radical innovations and industrial restructuring towards a low-carbon economy. A second part of this paper discusses the different channels through which carbon leakage may occur and their underlying intuition. This includes production (or operational leakage), understood as a shift of production volumes and hence market share; investment leakage, which includes changes in production capacity in response to non-harmonised climate regulation; leakage transmitted through resource markets – in particular through the price of fossil fuels; and finally indirect leakage, which is triggered by indirect carbon prices.

Kurzbeschreibung

Das Thema Carbon Leakage hat in vergangenen Jahren große Aufmerksamkeit erfahren – sowohl als Forschungsgegenstand, als auch als zentrales Thema politischer Diskussionen zur Klimapolitik. Als Folge gibt es ein unterschiedliches Verständnis dessen, was Carbon Leakage sei, und auch unterschiedliche Definitionen. Im Kern geht es dabei immer um unerwünschte Folgen einer Situation, in der verschiedene Länder eine unterschiedlich ambitionierte Klimapolitik verfolgen. Die einzelnen Diskussionsstränge unterscheiden sich aber darin, welche dieser Folgen im Mittelpunkt stehen, und welche kausalen Mechanismen dafür angenommen werden. Dieser Bericht gibt eine Übersicht über die verschiedenen Diskussionen rund um das Thema Carbon Leakage, fasst sie zusammen und strukturiert sie. Hierzu werden zunächst verschiedene Stränge der Diskussion dargestellt. So wurde Carbon Leakage einerseits als Problem gesehen, da es die Wirksamkeit unilateraler (bzw. nicht international harmonisierter) Klimapolitik verringert; als Problem ökonomischer Effizienz, da es die globale Verteilung der Minderungsanstrengungen verzerrt und so das Erreichen der weltweiten Klimaziele unnötig verteuert; als Problem der Wettbewerbsfähigkeit von Firmen, die sich mit einer ambitionierteren Klimapolitik konfrontiert sehen; und zuletzt als möglicher Gegensatz in der Diskussion um Innovationen und Investitionen für den Klimaschutz, um Dekarbonisierung und den Strukturwandel hin zu einer kohlenstoffarmen Wirtschaftsweise. Ein zweiter Teil des Berichtes geht dann auf die unterschiedlichen Kanäle ein, durch die Carbon Leakage stattfindet. Dazu gehört Produktionsleakage durch die Verlagerung von Produktionsvolumen und Marktanteilen; Investitionsleakage durch die Verlagerung von Produktionskapazitäten an schwächer regulierte Standorte; Leakage durch Ressourcenmärkte, insbesondere durch den Preis fossiler Brennstoffe, und schließlich indirektes Leakage, das durch überwälzte Kohlenstoffpreise ausgelöst wird.

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List of Abbreviations

CCS	Carbon capture and storage
EU	European Union
EU ETS	European Union Emissions Trading System
GHG	Greenhouse gas
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution (of Parties to the Paris Agreement, to the goals of the Paris Agreement)
IPCC	Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contribution
UNFCCC	United Nations Framework Convention on Climate Change

Summary

The discussion on carbon leakage is not new – but recently, the world has been changing in interesting ways: ambitious climate policy is no longer an exclusive pursuit of industrialised countries (if that ever was the case). The Paris Agreement is the most visible sign that an increasing number of countries around the world is committed to take action, or has already done so. In addition, it is becoming increasingly clear that effective global climate policies will require some form of decarbonisation, i.e. a drastic reduction in the use of fossil fuels, and eventually their phase-out. While this process will proceed at different speeds in different parts of the world, it does raise the question about the role of energy- (and material-) intensive industries in a decarbonised global economy, and how a structural change away from fossil fuels can be guided politically. As this paper argues, this also changes the terms of the carbon leakage debate. And it means that two central assumptions in the carbon leakage debate – that there will always be a demand for products from energy-intensive, fossil-based industries, and that they will always find a location to continue producing – may need revisiting.

This paper intends to structure and summarise some of the debates around carbon leakage, and to disentangle the various, often overlapping and intertwined threads and discourses around this issue. The issue of carbon leakage has seen a steep career, both in the academic realm, where it has been researched extensively for more than a decade, and in the political debate. The concept of carbon leakage intersects across different debates, some of which can draw on an intellectual tradition of more than two decades:

- One strand of the discussion sees carbon leakage as a problem that undermines the effectiveness of unilateral (or non-harmonised) climate policy. In this understanding, carbon leakage is a problem because some of the emission reductions achieved in one jurisdiction are offset by emission increases somewhere else – as a result climate policies are less effective than they appear to be. This effect was of particular concern in the Kyoto regime with its strict distinction between countries with (Annex I) and without binding emission targets (Non-Annex-I) – where leakage from the former to the latter would result in net additional emissions. To what extent this still applies in the post-Paris world with its broad diversity of different national climate targets is a matter of debate.
- A second strand discusses carbon leakage as a problem for the efficiency of non-harmonised climate policy: In the optimal situation with harmonised climate policy, production would be distributed across countries in accordance with their comparative advantage, including the ability to produce with low emissions. Carbon leakage distorts this process by shifting production and investment to countries with laxer climate regulations. As a result, goods are produced in an unnecessarily costly and polluting way, driving up the overall costs of production and reaching global climate targets.
- A third strand focuses primarily on the effects that unilateral climate policy (or, more generally, any difference in climate ambition between countries) has on the competitiveness of domestic industries, on location decisions of businesses, and on the first-mover advantages and disadvantages of climate regulation. In the political realm, this tends to be mostly a defensive debate, driven by the concerns of covered companies about impacts on their competitiveness vis-à-vis their international competitors – conducted either with the aim of lowering the ambition of climate policies altogether, or at least to secure assistance or some form of protection.
- Finally, a fourth (less explored) strand of the debate contrasts carbon leakage with the emerging discussion on radical innovations and industrial restructuring that will become necessary in the process of decarbonisation. The same industries that are most exposed to the risk of carbon leakage are also challenged to define their role in a future low-carbon economy. From this angle, the policy challenge is to encourage and enable low-carbon innovation rather than shielding industry from pressures to change and preserving the status quo.

A second part of the paper discusses the different channels through which carbon leakage may occur, the underlying intuition, their plausibility and the difficulties of observing them in practice.

- In the short term, the main form is operational or production leakage, whereby production volumes and associated emissions leak from plants in one jurisdiction to another. Importantly, this all happens within the confines of existing production capacities.
- As this process leads to changes in the production capacity (capacity decreases in the leakage source country, and increases in the leakage target country), it becomes a case of investment leakage, whereby differences in the stringency of climate regulation change investment flows, and (all else equal) result in higher investments in the countries with laxer regulation.
- A third channel of carbon leakage is transmitted through resource markets, in particular markets for fossil fuels, as an inevitable by-product of differential climate policy. As climate policy suppresses the demand for fossil fuels in one country or world region, with fossil fuel supply unchanged, this will result (all else equal) in fossil fuel prices that are lower than they otherwise would have been. This, in turn, gives an incentive to countries with less stringent climate policies to increase their consumption of fossil fuels.
- Fourth, there is also the case of indirect leakage – or, more specifically, leakage induced through the indirect carbon price. The carbon price works both directly (on actual green-house gas emitters) and indirectly (imposed on consumers of carbon-intensive products, provided that emitters are able to pass on the carbon cost). At least in theory, carbon leakage could also be triggered through the indirect carbon price, affecting the competitiveness in particular of large electricity consumers.

Thus, after more than a decade of research on carbon leakage induced by unilateral climate policies – and three decades of research on the relation between environmental regulation, firm competitiveness and investment decisions more broadly – the conceptual basis of the carbon leakage debate is well established, and many of the empirical links have been investigated. And yet, question marks remain, and new ones come up, all along the causal chain that describes carbon leakage: How strong is the leakage incentive from differences in carbon prices really? And how strong is it in comparison to some of the underlying trends – shifts in global demand, trends in commodity prices, structural change induced by technological change and / or by industrial policy? In the longer run, the question arises whether there will still be unregulated locations that investors would want to leak to – and will they remain unregulated over the time horizon of the investment? What could be a more adequate balance between the defensive leakage debate and the forward-looking debate on encouraging low-carbon innovation and the transformation towards a low-carbon economy?

Zusammenfassung

Die Diskussion um Carbon Leakage ist keineswegs neu – aber in der jüngeren Vergangenheit hat sich die Welt auf interessante Weise verändert, und damit hat sich auch der Rahmen für diese Diskussion verschoben. Es sind nicht mehr ausschließlich westliche Industrieländer, die ambitionierte Klimapolitik verfolgen. Das Pariser Abkommen ist das sichtbarste Zeichen dafür, dass eine wachsende Zahl von Ländern in aller Welt sich dem Klimaschutz verpflichtet fühlt, und entsprechende Maßnahmen ergreift. Zudem wird es zunehmend deutlich, dass wirksame Klimapolitik in der einen oder anderen Form eine Dekarbonisierung wichtiger Sektoren erfordert – die Verwendung fossiler Brennstoffe muss drastisch verringert, und schließlich ganz beendet werden. Während dieser Prozess in verschiedenen Ländern in unterschiedlicher Geschwindigkeit voranschreiten wird, stellt sich dennoch weltweit die Frage, welche Rolle energie- und ressourcenintensive Industrien in einer dekarbonisierten Weltwirtschaft spielen werden, und wie ein Strukturwandel zu einer postfossilen Wirtschaft politisch gestaltet werden kann. Dieser Bericht geht der Frage nach, wie diese Änderungen sich auf die Diskussion um Carbon Leakage auswirken. Insbesondere stellt sich die Frage, ob (oder wie lange) zwei zentrale Annahmen dieser Diskussion noch zutreffen: dass es immer eine Nachfrage nach den Produkten energieintensiver, fossil-basierter Industrien geben wird, und dass sich immer ein Standort finden wird, an dem diese Güter hergestellt werden.

Dieses Papier dient dazu, einige der Diskussionsstränge rund um das Thema Carbon Leakage zu strukturieren und zusammenzufassen, und die verschiedenen, zum Teil überlappenden und zum Teil verbundenen Diskurse zu entwirren. Das Thema Carbon Leakage hat eine steile Karriere hinter sich – sowohl in der wissenschaftlichen Welt, in der es seit über einem Jahrzehnt ausgiebig beforscht wurde, als auch in der politischen Diskussion. Als Begriff lässt sich Carbon Leakage mit verschiedenen Debatten verbinden, die zum Teil schon Jahrzehnte zurückreichen:

- Ein Strang der Debatte sieht Carbon Leakage als Problem für die Wirksamkeit unilateraler (oder nicht international harmonisierter) Klimapolitik. In dieser Interpretation ist Carbon Leakage deshalb ein Problem, da Emissionsminderungen in einem Land durch steigende Emissionen andernorts ausgeglichen werden: in der Folge ist die Klimapolitik weniger wirksam als es zunächst den Anschein hat. Dieser Effekt war insbesondere ein Problem im Kyoto-Regime der internationalen Klimapolitik, das auf einer strikten Zweiteilung von Ländern mit bindenden Emissionsgrenzen (Annex-I-Staaten) und solchen ohne Emissionsobergrenzen (Nicht-Annex-I-Staaten) basiert, weshalb Leakage aus der ersten in die zweite Kategorie in der Summe zu zusätzlichen Emissionen führt. Ob, und in welcher Weise, dieses Argument in der Welt des Pariser Abkommens mit seiner Vielzahl unterschiedlicher nationaler Klimaziele noch greift, bleibt zu diskutieren.
- Ein zweiter Strang betrachtet Carbon Leakage als Problem für die Effizienz einer nicht harmonisierten Klimapolitik: im Optimalfall einer komplett harmonisierten Klimapolitik würden sich die Produktionsanteile zwischen Handelspartnern allein nach deren komparativem Vorteil richten, einschließlich der Fähigkeit, Güter mit geringeren Emissionen herzustellen. Carbon Leakage verzerrt diese Verteilung, indem es Produktionsanteile und Investitionen verlagert in Länder mit schwächerer Klimapolitik. Infolge dessen werden Güter mit unnötig hohen Emissionen hergestellt, und werden die Kosten zur Erreichung globaler Klimaziele unnötig in die Höhe getrieben.
- Ein dritter Strang fragt nach den Wirkungen unilateraler, einseitiger Klimapolitik (oder allgemeiner nach den Effekten jeglicher Unterschiede in der Stringenz klimapolitischer Maßnahmen) auf die Wettbewerbsfähigkeit heimischer Industrien, auf die Standortwahl selbiger, und auf die Vor- und Nachteile für klimapolitische Vorreiter. Auf politischer Ebene wird diese Diskussion meist eher defensiv geführt, und dominiert von den Sorgen derjenigen Unternehmen, die ihre internationale Wettbewerbsfähigkeit gefährdet sehen, und die daher entweder auf ein geringeres Ambitionsniveau in der Klimapolitik drängen, oder die Kompensation für die befürchteten Wettbewerbsnachteile erhoffen.

- Und schließlich verbindet ein vierter, bislang eher weniger beleuchteter, Strang die Diskussion um Carbon Leakage mit der Frage nach radikalen Innovationen und industriellem Strukturwandel, die mit der Abkehr von fossilen Brennstoffen verbunden sein werden. Dieselben Industrien, die am stärksten dem Carbon-Leakage-Risiko ausgesetzt sind, stehen auch vor der Herausforderung, ihre Rolle in einer postfossilen Wirtschaft zu finden. Aus diesem Blickwinkel geht es daher eher darum, Innovationen zu fördern und disruptive Veränderungen zu gestalten, als Industrien vor dem Änderungsdruck zu schützen und den Status Quo zu bewahren.

Der zweite Teil dieses Berichts erörtert die verschiedenen Kanäle, durch die Carbon Leakage stattfinden kann, die zu Grunde liegende Logik, ihre Plausibilität und die Schwierigkeiten, sie empirisch zu messen.

- In der kurzen Frist ist das Produktionsleakage der wichtigste Kanal, im Zuge dessen Produktionsvolumen und die damit verbundenen Emissionen von einheimischen zu ausländischen Standorten verlagert werden. Dies findet dabei innerhalb der vorhandenen Produktionskapazitäten statt, und schlägt sich nieder in einem sinkenden Marktanteil der einheimischen Standorte.
- Wenn sich die Produktionskapazitäten ändern (Kapazitätsabbau an einheimischen Standorten und/oder Kapazitätserweiterung an ausländischen Standorten), spricht man von Investitionsleakage – dabei beeinflussen Unterschiede in der Stringenz der Klimapolitik die Investitionsströme, so dass das Land mit der schwächeren Klimapolitik zusätzliche Investitionen anzieht.
- Ein dritter Kanal verläuft durch den Markt für fossile Brennstoffe. Indem Klimapolitik in einem Teil der Welt die Nachfrage nach fossilen Brennstoffen verringert, führt sie – bei konstant bleibendem Angebot – dazu, dass der Preisen für diese Brennstoffe niedriger liegt als im Alternativszenario. Dadurch entsteht wiederum für Länder mit schwacher Klimapolitik ein Anreiz, mehr fossile Brennstoffe einzusetzen.
- Ein vierter Kanal wird als indirektes Leakage bezeichnet; treffenderweise handelt es sich um Leakage, das durch einen indirekten Kohlenstoffpreis verursacht wird. Der Kohlenstoffpreis verteuert einerseits die Emissionen selbst (direkte Wirkung). Wo die Emittenten aber in der Lage sind, den Kohlenstoffpreis ganz oder teilweise zu überwälzen, erhöht er auch den Preis von Gütern, die in der Herstellung kohlenstoffintensiv sind (indirekte Wirkung) – wie etwa Strom. Auch diese indirekte Wirkung könnte zu Leakage führen, etwa indem sie die Wettbewerbs- und Ertragsfähigkeit großer Stromverbraucher schmälert.

Nach mehr als einem Jahrzehnt Forschung zu Carbon Leakage durch nicht harmonisierte Klimapolitik, und nach drei Jahrzehnten Forschung zu dem Zusammenhang zwischen umweltpolitischer Regulierung, der Wettbewerbsfähigkeit von Unternehmen und Investitionsentscheidungen, ist der begriffliche Rahmen gut etabliert, und wurden viele der empirischen Zusammenhänge und Kausalitäten untersucht. Und dennoch werden viele Fragen weiterhin kontrovers diskutiert: Wie stark ist der Carbon-Leakage-Anreiz durch unterschiedlich ambitionierte Klimapolitik tatsächlich? Und wie stark ist dieser Anreiz im Vergleich zu vielen anderen Trends, die Investitions- und Produktionsentscheidungen beeinflussen – so wie Veränderungen in der weltweiten Nachfrage, Veränderungen der Rohstoffpreise, oder auch Strukturwandel durch technologische Veränderung oder durch politische Weichenstellungen? Auf längere Sicht stellt sich die Frage, ob es noch unregulierte Standorte geben wird, an denen potentielle Investoren investieren wollen würden – und wie lange diese Standorte noch frei von klimapolitischer Regulierung bleiben werden? Und schließlich stellt sich die Frage, wie eine bessere Balance gelingen kann zwischen der defensiven Diskussion um Carbon Leakage und der proaktiven Frage, wie die nötigen Innovationen und Investitionen für eine kohlenstoffarme Wirtschaftsweise auf den Weg gebracht werden können.

1 Introduction

This paper aims to structure and summarise some of the debates around carbon leakage, and to disentangle the various, often overlapping and intertwined threads and discourses around this issue. The issue of carbon leakage has seen a steep career, both in the academic realm, where it has been researched extensively for more than a decade, and in the political debate.

As a concept, carbon leakage is not entirely new. To the contrary, the (political and academic) debate on carbon leakage builds on an understanding of the interactions between environmental regulation, industrial competitiveness and location decisions of industries that was developed more than two decades ago (Birdsall and Wheeler 1993; Jaffe et al. 1995; M. Porter and van der Linde 1995; M. E. Porter and Linde 1995). Although the concept of carbon leakage is more recent – having risen to the forefront of political and academic debates along with the increasing attention to climate protection, and in particular the introduction of the EU Emissions Trading Scheme – it does pick up several strands of the debate that has been going on since the 1990s. Yet, despite two decades of research, many of the empirical questions remain unresolved: does environmental regulation reduce or improve competiveness of domestic industries? Does weaker environmental regulation make a location more attractive for foreign investment?

But the world is changing in interesting ways. Much of the academic research, and most of the political debates around carbon leakage was based on the premise that ambitious climate policy is exclusively a pursuit of Annex-I-countries or the EU alone, whereas the rest of the world was not taking action. The adoption of the Paris Agreement in 2015 shows that this is no longer an adequate representation of reality: having been adopted unanimously by 195 countries, and with 162 parties (representing 189 countries) submitting their "intended nationally determined contribution" to reaching the objectives of the agreement, the Paris Agreement is the most visible sign that an increasing number of countries around the world is already taking action, or is in the process of introducing climate policies.

At the same time, it is becoming increasingly clear that effective global climate policies will require some form of decarbonisation, i.e. a drastic reduction in the use of fossil fuels, and eventually their phase-out. While the transformation to a low-carbon economy is a declared objective of the EU, the need for such a transformation is (implicitly or explicitly) acknowledged also in other parts of the world. The objective of the Paris Agreement to establish a balance between anthropogenic greenhouse gas emissions and sinks in the second half of the 21st century is somewhat weaker, but it too is based on the premise that rapid reductions of global emissions will be necessary in the coming years. While decarbonisation will proceed at different speeds in different parts of the world, it does raise the question about the role of energy- (and material-) intensive industries in a decarbonised global economy, and how a structural change away from fossil fuels can be guided politically.

Taken together, these two trends mean that two central assumptions in the carbon leakage debate – that there will always be a demand for products from energy-intensive, fossil-based industries, and that they will always find a location to continue producing – are becoming increasingly questionable.

It should be noted that this paper focuses exclusively on the forms and channels of carbon leakage, providing an overview of the relevant literature to assess their relative significance. The paper does not touch upon the policy measures against carbon leakage, nor on their efficacy or their political or legal feasibility.

2 Definitions of Carbon Leakage

2.1 Common Definitions of Carbon Leakage

The notion of carbon leakage has received much attention in recent years, both as a subject of research, and even more as an issue in the political debate on climate policy. As a consequence, there are different understandings of what constitutes carbon leakage, and different definitions.

The IPCC, in its fifth assessment report, defined carbon leakage as "phenomena whereby the reduction in emissions (relative to a baseline) in a jurisdiction / sector associated with the implementation of mitigation policy is offset to some degree by an increase outside the jurisdiction / sector through induced changes in consumption, production, prices, land use and / or trade across the jurisdictions / sectors", adding that "leakage can occur at a number of levels, be it a project, state, province, nation, or world region" (Allwood et al. 2014, 1265).

A further, more technical definition of carbon leakage is offered inter alia by the IEA, defining carbon leakage as "the ratio of emissions increase from a specific sector outside the country (as a result of a policy affecting that sector in the country) over the emission reductions in the sector (again, as a result of the environmental policy)" (Reinaud 2008, 3). Similar definitions have been put forward e.g. by Quirion 2010; Kuik, Branger, and Quirion 2013; Marcu et al. 2013. A constituting element of all definitions of carbon leakage is that it is driven by differences in the stringency of climate policies in different jurisdictions or sectors. At the extreme, this can be between jurisdictions (or sectors) where one is covered by climate policies and the other one not, or where one has a binding emission limit and the other one does not. But in principle, leakage will also occur where climate regulations apply in bothjurisdictions (or sectors), but differ in their ambition.

Where carbon leakage is defined as a ratio between emission reductions at home, and emission increases abroad, the leakage ratio will also depend on the carbon intensity of production abroad. At the one extreme, if the fall in domestic production is entirely offset by a production increase abroad, and if the carbon intensity of production is higher abroad, a leakage ratio of more than 100% would be possible. However, this possibility requires strong assumptions, and is therefore seen as unlikely (Blanco et al. 2014, 386; Kuik, Branger, and Quirion 2013, 16). At the other extreme is the case of "positive carbon leakage", the possibility of energy-intensive processes relocating to regions with an abundance of renewable energy resources – such as Iceland, Canada, Norway or Brazil, with good wind or bioenergy resources or with large hydropower or geothermal capacities (Åhman and Nilsson 2015, 103; Görlach et al. 2008, 9). In this case, the leakage ratio would be 0%, despite the fact that a shift of production has taken place.[1]

A point to note is that the definitions quoted above describe carbon leakage in terms of the relocation of emissions: *carbon leakage means that part of the emission reduction achieved through climate policies is offset by an emission increase somewhere else (in another country or in another sector).* Carbon leakage, in this view, is a problem since it undermines the ***effectiveness*** of climate policies. In contrast, the political discussion on carbon leakage tends to see it above all as a problem of ***efficiency*** (or fairness), in the sense that climate policies of different stringency distort the level playing field for market actors, and distribute the allocation of the mitigation burden in an inefficient and thus unnecessarily burdensome way, thereby penalising front-runner countries with more ambitious climate policy.

In the broader debate on carbon leakage, several other distinctions have been put forward in the literature. While they go beyond the understanding of carbon leakage that underlies most of the policy and

[1] A further complication stems from the nature of the domestic emission reductions. If they have occurred underneath a fixed, absolute emissions cap – such as the "assigned amount" of emissions under the Kyoto Protocol; if it is assumed that an overachievement of the cap is not possible, meaning that the domestic emission reduction will be offset by an emission increase in another part of the economy; and if the emission increase abroad is not covered by a comparable cap, the effect will always be a net increase in emissions (see also section 2.3.1).

academic debate on carbon leakage, they are shortly discussed below for the sake of clarity and completeness.

First, the IPCC's fifth assessment report discusses the distinction between **weak and strong leakage**. In this understanding, strong leakage refers to the relocation of emissions driven by differences in climate regulation (as per the definitions by IPCC and IEA quoted above). Weak leakage, by contrast, refers to the relocation of emissions that cannot be attributed to climate policy, but is instead induced through non-climate-policy factors, such as general shifts in the pattern of production and consumption across countries (Blanco et al. 2014, 385).[2] It should be noted that while these trends and their effects are recognised in the literature, they would not be considered as a type of carbon leakage in the European debate. Rather, they are regarded as a consequence of structural changes in the world economy, e.g. in the wake of trade liberalisation. For the purposes of this paper, the focus will be exclusively on what the IPCC's fifth assessment report refers to as "strong leakage", i.e. changes induced through differences in climate policy.

A second boundary case concerns **domestic leakage across sector boundaries**. The IPCC definition introduced above points to the possibility that carbon leakage occurring at the system boundaries of any partial climate regulation. These system boundaries can be national or provincial boundaries, where one jurisdiction regulates carbon emissions more strictly than another. But they can also be sectoral boundaries, or size thresholds, which result in a situation where some emitters are covered and others are not. For instance, in-country leakage could occur from larger to smaller firms, if only firms above a certain size threshold face a carbon price. Or there could be leakage across sector boundaries, if emissions related to certain products are covered by climate regulations, but not those of other products that are close commercial substitutes. For this paper, the focus will be on carbon leakage across spatial boundaries, due to differences in climate ambition between different jurisdictions.[3]

Leaving aside these non-conventional interpretations of carbon leakage, most academic and political discussions of carbon leakage start from the following premises:

1. Carbon leakage results from **differences in the stringency of climate policies** between jurisdictions.
2. These differences affect the **relative cost of production between jurisdictions**, and therefore the relative profitability and ultimately the production or investment decisions of polluting companies.
3. As a consequence of these differences in regulation and associated costs, **economic activity in the polluting sectors declines** in the jurisdiction with stricter climate policies, and increases in those with less stringent climate regulation.

[2] For reasons unrelated to climate policy, emission-intensive industries have grown strongly in non-Annex-I countries over the last decades, while they have stagnated or declined in Annex-I-countries. Yet, as some scholars have pointed out, a sizeable share of these emission-intensive goods are produced for export, which means that the emissions associated with the domestic production of goods exceeds the consumption-based emissions. This discrepancy is balanced in the form of "embodied emissions" of traded goods and commodities (see e.g. Lininger 2015; Wiebe and Yamano 2016).. Studies estimated that up to 5.3 Gt of CO_2, or 21.5% of global CO_2 emissions (in 2001), take the form of such embodied emissions (Peters and Hertwich 2008): in a production-based emission accounting framework, they are attributed to the country of production (where the emission occurs); but in a consumption-based accounting framework, they would end up in the country of final consumption.

[3] A third boundary issue is also flagged up in the IPCC's fifth assessment report: in the case of overlaps between ETS and other climate policy instruments ("nested regulation" in IPCC terminology), the situation may arise whereby complementary climate policies reduce emissions that are covered by a quantitative limit (such as an ETS cap), giving rise to emissions in other sectors. However, while there has been some discussion of this effect and its effects on climate policy design (Sinn 2008), this is not an interpretation of carbon leakage that resonates with the mainstream of the (political and academic) debate on carbon leakage.

4. This results in increased emissions in the less strictly regulated jurisdiction, offsetting (part of) the emission reductions achieved in the more strictly regulated jurisdiction, and thus **undermining the effectiveness of domestic, unilateral climate policy**.
5. By definition, the above effect is always described **in comparison to an (implicit) baseline**, in which there are no differences in the stringency of climate regulation.

2.2 Problems of Defining Carbon Leakage

One challenge of observing carbon leakage is that it can always only be measured in comparison to a counterfactual scenario, which assumes away any differences in the stringency of climate policy – either in the sense that there is no domestic climate policy, or by assuming an equally stringent climate policy in the foreign country which is assumedly the target of leaking industries.[4]

This points to a problem of attribution: beyond climate policy (and its effects on relative production costs), there are plenty of other factors that will determine a company's production and investment decisions. These include access to markets (and assumptions about their future development), cost and availability of skilled labour, access to raw materials, energy and other inputs to the production process (and their cost), access to product markets, customer relations, access to capital markets, available infrastructure, transport costs, risks associated with exchange rate fluctuations, political stability of foreign governments and access to the legal system, investment subsidies or other support granted by the recipient country, local industry networks and access to integrated production processes, non-environmental (or non-climate) regulation and the associated cost, e.g. workplace safety, etc. (Jaffe et al. 1995, 146; Bassi and Zenghelis 2014, 11). Many of these parameters escape a precise quantification, and rather depend on value judgements by the investor and her personal beliefs and expectations, which creates a substantial obstacle for an empirical analysis of these different factors and their relative importance. However, for those parameters where a quantitative evaluation is possible, the evidence suggests that other factors tend to have a much stronger influence than the cost of energy, let alone the cost of climate regulation (Aldy and Pizer 2011, 4; Neuhoff, Acworth, Dechezleprêtre, et al. 2014, 19).

One point to note is that, aside from climate policies, most of the other factors do not favour production or investment in Europe, but rather in the emerging markets around the world – most notably access to (growing) markets in the emerging economies, as well as the cost of labour. Thus, while it is possible in theory to construct a counterfactual scenario that assumes away any differences in climate policy, plenty of other factors remain in such counterfactuals that incentivise a relocation of production and investment towards other countries. For instance, aluminium production in the EU has been declining since the late 1990s, i.e. long before the introduction of the EU ETS. This trend was driven, inter alia, by high energy prices in Europe, shrinking margins and overcapacity due to the economic crisis, stricter anti-trust regulation in Europe, and removal of tariffs for imported aluminium (Sartor 2013, 9). Other research suggests that similar trends can be observed in the steel sector: over the last decade, global market shares have shifted markedly from European towards Asian manufacturers. Yet most of this can be attributed to declining demand in Europe, whereas demand in many Asian countries has surged, driven by massive investments into infrastructure, construction and machinery

[4] One implicit premise for the carbon leakage debate is that carbon leakage is only perceived as a concern in the jurisdiction with higher climate ambition – i.e. the jurisdiction where leakage originates. In the jurisdiction with lower climate ambition, i.e. the recipient of carbon leakage, leakage would not necessarily be viewed as resulting from climate policies abroad, but simply as foreign direct investment, or as success of domestic producers in global competition. A second implicit premise in the (European) debate, fuelled by the experience of the first and second Kyoto commitment periods, is that EU climate policies are assumed to be more ambitious than everybody else's climate policies – or, in the more extreme version, that only the EU has climate policies to speak of. To which extent these premises are justified by the facts, also in the light of the Paris Agreement and the developments at national level that it sparked, is a matter of empirical analysis, and needs to be continuously monitored and updated.

(Bolscher et al. 2013, 23). In particular, the Chinese steel sector expanded its capacity massively, allowing it to not only supply the domestic demand, but also to become a net exporter of steel (Neuhoff, Acworth, Ancygier, et al. 2014, 8). In the wake of the 2008-2009 economic crisis, and due to a slowing down of domestic demand in China, massive overcapacities have built up in the Chinese steel sector. These overcapacities have doubtlessly made competition stiffer in Europe, and have led to plant closures – yet they are not attributable to differences in climate policies (Turcea and Kalfagianni 2015, 32).

In the majority of situations, the (relative or absolute) loss of production and investment from Europe to emerging economies will therefore already be part of the long-term basic trend against which any other policy-induced change, including carbon leakage, is estimated. Carbon leakage, in other words, is a relatively minor factor that could exacerbate and accelerate existing trends, which would also persist in the absence of any difference in climate policies.

This points to another, related problem of measurement and attribution: differences in climate policy, and its effects on the relative costs of production abroad and at home, will usually be a relatively minor factor in firms' decision making, both regarding operational and investment decisions (Aldy and Pizer 2011, 4). Particularly since 2010, there have been dramatic shifts in some of the other factors that influence such decisions – in particular the relative prices of energy resources (e.g., in the wake of the US shale gas boom and the current overproduction of crude oil), but also the economic activity in different parts of the world and, as a result, demand for the output of energy-intensive industries such as steel and cement. These influences can work in different directions: when the economy in an emerging economy booms, there is little spare capacity that could be used to supply the EU market, hence the leakage risk is much smaller. In contrast, when economic activity in an emerging economy contracts, the resulting excess capacity poses a substantial competition for European producers. This means that the baseline against which any carbon leakage would be estimated is already highly dynamic, and influenced by several strong trends, which makes it harder to isolate the influence of differences in carbon policy.

2.3 Carbon Leakage and its Link to Different Discourses

One of the difficulties in discussing carbon leakage is that the concept is linked to different discourses, and therefore used in different, sometimes overlapping ways. Some of these discourses – such as whether regulation is detrimental to competitiveness of domestic industries, or perhaps even conducive – have been entertained for decades and remain empirically undecided.

One way of disentangling these discourses is to consider why carbon leakage would be seen as a problem. The most relevant answers are:

1. Carbon leakage as a problem for **the effectiveness of climate policy**: In this understanding, carbon leakage is problematic since it undermines the effectiveness of unilateral, non-harmonised climate policy. Inconsistent policies in different parts of the world mean that part (or all) of the emission reduction achieved through domestic policies in one location is offset by emission increases somewhere else, leading to higher global emissions than in the case without carbon leakage. This offset has to be subtracted from the effectiveness of domestic policies – and renders them less effective than they could be, and appear to be.
2. Carbon leakage and the (global) **efficiency of climate policy:** based on the assumption that there is an economically efficient, cost-minimising distribution ("allocation") of GHG reduction efforts and GHG-intensive production activities across countries globally, unilateral or uneven climate policy can be seen as leading away from this distribution, making climate policy unnecessarily costly for the world as a whole.

3. Carbon leakage as a problem of **economic competitiveness**: In this understanding, carbon leakage is evidence of the impacts of climate regulation on the global competitiveness of domestic industries. These impacts are seen as harmful and unfair, as they tilt the level playing field between competitors abroad and at home, and lead to the loss of income and jobs. Furthermore, it may deter nations from taking unilateral climate action, or increasing their ambition.
4. Carbon leakage and **structural change towards deep decarbonisation**: In this understanding, carbon leakage runs the risk of leading into a defensive, short-term debate, shielding emission-intensive industries not only from competitive disadvantages, but from any incentive to change. If the objective of carbon leakage policies is merely to preserve emission-intensive industries in their present form, they will eventually run into conflict with the transformation towards a low-carbon economy, which will incorporate some element of structural change.

The following section will discuss these four interpretations of carbon leakage, and why carbon leakage is seen as a problem.

2.3.1 Leakage and the Effectiveness and Global Consistency of Climate Policy

A common interpretation hinges on the fact that carbon leakage undermines the effectiveness of domestic emission reductions, if emission-intensive activities are offshored from regulated countries to countries with fewer climate regulations, or none at all. The effectiveness of domestic climate policies thus needs to be discounted to account for the emission increase abroad.

A particular problem arises in the case of leakage from countries / sectors with an absolute emission cap to non-capped countries / sectors. For instance, this is the case for leakage from Annex-I countries with an absolute emission limit (assigned amount) under the Kyoto Protocol to non-Annex-I-Countries, that have no such limit. In those situations where a country's emissions are below the cap, carbon leakage will translate into net additional emissions: In this case, carbon leakage means that emission reductions achieved through domestic climate policies may succeed in reducing emissions at home, but these reductions are (partly) compensated by emission increases abroad. Ultimately, thus, what seemed like a domestic emission reduction, partially ends up as a mere redistribution of emissions between countries. Yet if that domestic emissions are below the national cap to begin with, the domestic emission reduction in the leakage-affected sectors simply opens up space for other sectors (e.g., transport) to increase their emissions until the cap is reached.

The latter argument, however, becomes less straightforward as the classic Kyoto divide between entirely regulated (Annex-I) countries with a hard and binding cap, and entirely unregulated (Non-Annex-I) countries with no such constraint, becomes more blurred. If the carbon leakage recipient country has some kind of national emission reduction target in place, the additional "leaked" emissions would count against the achievement of this target, and would thus necessitate stricter emission reduction policies in other parts of the economy. Whether or not there will still be some amount of carbon leakage will then depend on the nature of the mitigation target in the leakage host country. If the leakage host country has set itself an absolute emission limit, carbon leakage will not result in net additional emissions – unless the limit has been set so loosely that it is unlikely to become effective in practice. If the leakage host country has set itself a relative emission limit, e.g. linked to GDP, carbon leakage may result in some net additional emissions – since carbon leakage will increase not only the emissions, but also GDP in the leakage recipient country compared to the baseline. Depending on whether the "leaked" activity has a higher / lower CO_2 intensity than the rest of the economy, it may still be the case that carbon leakage will increase pressure on the recipient country's government to take additional efforts in other sectors, thus offsetting some of the net additional emissions.

With the entry into force of the Paris Agreement, we now live in the post-Paris world, where 162 parties to the UNFCCC – representing 189 countries world-wide – have formally announced some kind of

climate policy target as part of their Intended Nationally Determined Contributions (INDCs) submitted to the UNFCCC. In this world, the binary distinction of the Kyoto Protocol no longer applies, which distinguished between constrained (Annex I) countries – with a firm and binding emissions cap in place – and unconstrained (non-Annex I) countries – which are only bound by the general, unspecified obligations emanating from the UN Framework Convention on Climate Change, but which are essentially free to emit as much as they chose, without fearing consequences. While there are huge differences regarding the type of target, the level of ambition it embodies and its effect on constraining emissions, almost all potential leakage recipients now face some kind of trade-off between receiving leaked production from OECD countries and achieving their NDCs.

2.3.2 Leakage and Global Greenhouse Gas Efficiency

A second strand connects the effect of carbon leakage on the global GHG efficiency of production. Based on the assumption that there is an economically efficient, cost-minimising allocation of GHG reduction efforts and GHG-intensive production activities across countries globally, unilateral or uneven climate policy can be seen as distorting this distribution, leading to carbon leakage and thereby making it unnecessarily costly to achieve a common global GHG reduction goal. Taking the demand for industrial products as given (for the sake of the argument), the carbon footprint of producing a given amount of output will depend on where production takes place – in which plants, under which conditions, using which inputs. There are different ways how the physical redistribution of production (and associated emissions) between plants across countries as a consequence of unilateral or uneven climate policy may affect the global GHG efficiency of production.

At the most basic level, in a world without trade distortions – including homogenous climate policies – production would be distributed based on countries' comparative advantage.[5] Carbon leakage distorts this distribution – since plants in carbon leakage recipient countries take on a higher share of production, simply due to the absence of CO_2 costs, even though their net production costs are higher. This departure from the globally optimal distribution leads to an increase in overall production cost, and thus a net loss in overall welfare.

Next to this general production cost argument, another aspect of the global greenhouse gas efficiency relates to the relative CO_2 intensity per product in the carbon leakage recipient countries, compared to the one in the country from which the production is leaving.

- The "pollution haven" argument maintains that high-emitting sectors are attracted by lax environmental regulation, and will take advantage of this laxer regulation to save costs by using more polluting technologies. Carbon leakage into pollution havens thus leads to dirtier production overall (and thus away from the theoretically optimal distribution of polluting activities), as production shifts from relatively cleaner, less polluting plants in the regulated countries, to less efficient plants in the non-regulated countries.
- A countervailing hypothesis is that the GHG efficiency of a plant will depend much more on its age than on its physical location. Thus, particularly for installations serving the global market and producing to global standards, new installations will be built at the technological frontier, using effectively the same state-of-the-art technology irrespective of where they are built. Since the GHG efficiency of installations improves over time, new installations will tend to be more efficient than older ones. If these assumptions hold, the investment that comes with carbon leakage will generally improve the GHG efficiency of production. As emitting sectors invest in new installations abroad, these new installations will tend to be at least as clean as the older, domestic installations

[5] "Comparative advantage" (Krugman, Obstfeld, und Melitz 2018) refers to relative costs in different producing countries (or regions). In addition to the costs as such, they include the possibility that one country can produce a certain product cheaper than another country, but that there is yet another product where it has an even larger cost advantage to the other country. As a result, it should produce this latter product, while (if total production capacity is limited) it is beneficial for both countries that the other country produces the other product, where the cost difference is smaller.

they replace. To the extent that this hypothesis holds true, any investment into new installations, whether at home or abroad, would thus improve the GHG efficiency of global production.

- As an extreme case of the latter, there is also the possibility of "clean leakage" – the relocation of highly-emitting sectors to locations where there is an abundant supply of low-carbon fuels (e.g. natural gas or hydroelectricity). This trend can be observed e.g. in the aluminium industry, where much investment goes to production sites with a reliable hydropower supply (Sartor 2012). In a world with a given demand for energy-intensive products, but a limited global carbon budget, such clean leakage would actually be a desirable feature, as it brings the global economy closer to the ideal of a GHG-efficient allocation of production activities. Concentrating the most energy-intensive parts of the production process in places with an abundant supply of clean energy would mark a significant contribution to decarbonising global value chains.

2.3.3 Leakage and Competitiveness

In the current EU policy debate, this is the most prominent interpretation of carbon leakage: carbon leakage is seen as evidence that European climate policies have reduced the competitiveness of domestic industries, by increasing their production costs relative to their competitors who do not face comparable climate constraints. This situation is regarded as fundamentally unfair, as countries with more ambitious climate policies (who thus contribute to the global public good of a stable global climate) are penalised in the form of losing business shares (and thereby income and jobs) to other countries that have less ambitious policies. Thus, the risk of carbon leakage, and the fear of a loss of competitiveness (and the associated losses of jobs, investment, tax revenue etc.), may act as a deterrent for countries that consider increasing their ambition. In a more extreme interpretation, it has been argued that countries could even be tempted to *lower* existing standards of environmental regulation, in an attempt to *increase* the competitiveness of domestic industries, and to become more attractive for new investment. If other countries responded by lowering their environmental standards, this could even lead into a negative feedback loop – a "race to the bottom", in which countries entered into a competition of lowering their environmental standards (Sheldon 2006).[6]

Several points can be made in critique of this narrative, mostly in relation to the concept of competitiveness – which is, in fact, a nebulous concept, which is regularly invoked in policy debates, but which is neither well-defined, nor grounded in rigorous economic theory (Kuik 2014, 8).[7] One of the key questions is whose competitiveness is affected by climate policies – that of the EU economy vs. the economies of non-EU-countries such as China, or that of companies based in the EU? As Paul Krugman

[6] This hypothesis can be linked to the "pollution haven" argument (Copeland and Taylor 2004), according to which countries would voluntarily turn themselves into havens for the most polluting industries by essentially abolishing all environmental regulations and standards, see also section 2.3.1 below). It should be noted that both hypotheses are disputed, as they do not seem to be supported by the empirical evidence (Jaffe et al. 1995; Birdsall and Wheeler 1993).

[7] One of the consequences is that there is not a single, universal definition of competitiveness. Possibly least contested is the notion of competitiveness at the firm level, which describes the ability of a firm to sell goods and service in the market at a profit, and thereby to stay in business (Adams 1997). Paul Krugman offers a somewhat more elaborate description of competitiveness at the firm level: "The bottom line for a corporation is literally its bottom line: if a corporation cannot afford to pay its workers, suppliers, and bondholders, it will go out of business. So when we say that a corporation is uncompetitive, we mean that its market position is unsustainable, that unless it improves its performance, it will cease to exist" (Krugman 1994, 31). To this firm-level definition of competitiveness, an analytical framework put forward by the OECD in 1997 added to more dimensions: "Competitiveness ***at the sectoral level*** refers to the aggregate competitiveness of the firms that operate within a given sector in an economy, compared to international rivals; [and] Competitiveness ***at the national level*** refers to an ability of a country to increase its economic

standard of living" [emphasis added] (Adams 1997) – see above for a summary of Krugman's critique why competitiveness defined at the national level is a particularly difficult concept. A further OECD working paper expands on this categorisation by elaborating that "it is useful to think about competitiveness as an ability. As this ability itself is difficult to gauge, most of the definitions that we encounter in literature and the measures used in empirical studies in fact address determinants of competitiveness such as productivity) or consequences of competitiveness (such as accounting-based or stock-market-based measures of economic performance at the firm level; volume of activity, market shares, and trade flows at the sectoral level; and trade and investment flows and growth at the national level)." (Lankoski 2010, 14)

famously argued, the notion of "national competitiveness" is a dangerous obsession: while the concept of competitiveness makes sense when applied to private companies, the same is not true for national economies. Thus, he argues, the false analogy of applying competitiveness to national economies leads to the fallacy of seeing international trade as a zero-sum game, i.e. that one country's gain must be another country's loss. While this is true for the competition between companies, it does not apply to trade between countries, which is in fact a positive-sum game.[8] Second, the attempts to measure competitiveness at the national level, Krugman argues, result in a misguided focus on a country's trade balance as a measure of economic success – which, in fact, does not allow inferences about the strength or weakness of an economy, or the welfare of its citizens, as neither are huge and persistent trade account surpluses necessarily a sign of success, nor are trade account deficits a sign of failure. And finally, he considers the focus on competitiveness as dangerous as it distracts from the really important issues (such as productivity) – which, however, depend on an array of factors and thus require complex solutions, rather than the quick fixes that seem to be available for national competitiveness (Krugman 1994).

And yet the situation does not improve much when the "competitiveness of the EU economy" is replaced with the "competitiveness of European companies" – since this raises the question which companies qualify as European? In today's globalised economy, the place where a company was originally founded, where it is headquartered and / or formally registered, the location of its main physical assets, the nationality of its top management, its labour force and its shareholders, and the place where it pays the bulk of its taxes may all diverge; and moreover, some of these parameters (in particular registration, ownership and tax incidence) may also change rapidly.[9]

Applied to the carbon leakage debate, this means that a debate on how climate policy affects Europe's competitiveness, or the competitiveness of European companies, is misguided, since the main concepts of the debate are misleading or poorly defined. The discussion worth having is rather whether climate policy makes certain production processes so much more expensive domestically than abroad that it would threaten *the feasibility of the EU as a production location*.

A second, long-standing debate revolves around the question *how* environmental regulation actually affects competitiveness of companies whose production processes are being regulated (Birdsall and Wheeler 1993; Jaffe et al. 1995). The default assumption in the carbon leakage debate (and in the debate on environmental regulation more broadly) is that regulation adds to the cost of domestic production – be it through paying a carbon price, or through the cost of complying with environmental regulations, e.g. by investing in emission abatement. Competitors abroad, who are not regulated, do not face this cost, hence environmental regulation reduces the competitiveness of domestically produced products.

Different strands of arguments have been put forward to nuance or reverse this assumption.

- In 1991, Michael E. Porter put forward the hypothesis that well-designed and well-enforced environmental regulation could induce innovation, and thereby improve competitiveness: under normal conditions, firms suffer from market imperfections, such as organisational inertia or asymmetric information, which prevents them from organising their production efficiently. Well-designed

[8] In contrast to competition between companies, trade between countries is less about securing a larger share of a given pie, but about enlarging the pie. This is also due to the fact that countries' economies are more interdependent than companies are: if the economy of a trading partner flourishes, they will also import more – which is not necessarily the case at company level.

[9] That does not take away the fact that some companies may be firmly rooted within a particular region – for instance because they depend on access to skilled labour or to unique (natural) resources, on a particular type of infrastructure (or combination of different infrastructures), on a tightly integrated regional supply chain or other local networks, or because regional identity is an intrinsic part of the brand identity – or simply since owners and management feel committed to a particular city or region. And yet, even for an industry that is most firmly rooted in a particular region to the point of being an icon – Scottish whisky distilleries – only one quarter of the distilleries are locally owned, and more than 40% are owned by companies based overseas, including from France, Japan, Thailand and Bermuda (*HeraldScotland* 2015).

regulation could prompt firms to change their business practices in order to comply with the regulation, in the process increasing efficiency through innovations, and ultimately improving their competitive positions (M. Porter and van der Linde 1995, 98; Rubashkina, Galeotti, and Verdolini 2015, 289). There are different interpretations of this "Porter Hypothesis": in its weak form, the regulation-induced innovation is understood to offset part of the competitive disadvantage brought about through environmental regulation in the form of higher cost. In its strong form, the efficiency gain from innovation would even overcompensate the cost of regulation, thus leading to a net gain in competitiveness.

- A similar, but more fundamental argument maintains that environmental regulation could also give the regulated firms a first-mover advantage: as regulation forces (or incentivises) domestic firms to intensify their efforts on climate-friendly technologies, these firms build up technological knowhow. If other countries eventually decide to pursue similar environmental policies, the technological knowhow constitutes a comparative advantage vis-à-vis competitors, which allows domestic firms to capture a share of newly emerging markets (Kuik, Branger, and Quirion 2013, 20).
- More specifically for the EU ETS, there is an open question as to whether the EU ETS has actually imposed a net burden on the covered companies, or whether it has given rise to a net profit. There are some elements that clearly constitute a net cost – such as the cost of setting up administrative process to monitor, report and verify emissions, costs associated with the registry account or transaction costs for buying or selling allowances. But there is also evidence that the EU ETS has led to significant additional profits for industrial emitters. These additional profits come in the form of surplus allocation of allowances, which installations received for free and were able to sell at a profit, but also in the form of windfall profits: there is evidence that industrial companies were able to increase the prices of their products by factoring in the opportunity costs of allowances, thus passing these costs on to consumers. Since the emitting installations had received the allowances free of charge, the additional revenue translates into an additional net profit (de Bruyn et al. 2010; de Bruyn, Schep, and Cherif 2016).

2.3.4 Carbon Leakage, Radical Innovation and Structural Change towards Decarbonisation

In the short to medium run, there is still considerable potential for emission reductions within emission-intensive industries through the wide-scale application of best available technologies, amounting to a mitigation potential of 10-30% (Åhman and Nilsson 2015, 97). In the long run – i.e. beyond 2030 – emissions from industry will need to be reduced further. The technologies through which this could be achieved remain uncertain: to some extent, biomass can be used both as a fuel and as a feedstock; yet supply of biomass is limited and competition for the use of the limited resource is strong. Second, electrification offers an option for some processes – either through the direct use of electricity for heat generation, or indirectly through the use of hydrogen. Yet, such options would only contribute to decarbonisation if the power supply itself has become completely decarbonised, and, again, there will be competition from other sectors and uses, such as transport or space heating. Third, carbon capture and storage (CCS) may play a role as a backstop technology; yet the applicability of CCS to industry appears even more complicated than for power generation, due to the multitude of different emission sources with different CO_2 concentrations, and the limited space for post-process capture (Åhman and Nilsson 2015, 98). And finally, there is the option of (currently highly uncertain) "breakthrough technologies" such as alternative, CO_2-absorbing cements, which would radically change the production process and the emissions profile of certain sectors.

And yet, while there is still potential for significant emission reductions in industry, modelling of deep decarbonisation scenarios suggests that decarbonisation will also include changes in the sectoral structure of the economy. Thus, for instance, Meyer, Meyer, and Distelkamp 2014 conclude that achieving a decarbonisation of Europe's economy will also require a dematerialisation of its economy,

i.e. a drastic reduction of its consumption of materials.[10] While according to their modelling results, the overall economic effects of a decarbonisation would likely be very small, there would be strong structural effects in the most sectors that produce material inputs to the economy – which also tend to be among the most energy- and resource-intensive, i.e. pulp and paper, chemicals, rubber and plastics, other non-metallic minerals and basic metals.

However, the current EU climate policy by and large lacks the tools to bring about such long-term structural changes and innovation towards deep-decarbonisation. There is disagreement whether a carbon price by itself could be sufficient to bring about the necessary shifts in long-term technological trajectories and infrastructure, and to stimulate innovation at the level and the pace needed (Somanathan et al. 2014, 1173; Grubb 2014), yet there is broad consensus that a strong carbon price should definitely be a central element of a comprehensive policy package for decarbonisation. In the EU climate policy, ideally, it would have been the role of the EU ETS to provide a strong incentive for decarbonisation through a clear carbon price signal for covered sectors. Yet the EU ETS has so far failed to deliver this incentive, because of the oversupply of allowances and the resulting low price levels, but also because of the decision to grant continued free allocation of allowances to industrial emitters, justified with the fear of carbon leakage (Dupont and Oberthür 2015, 254).

There is therefore a disconnect between the short- and long-run climate policy debates at the EU level. In the long run, the need for decarbonisation is acknowledged, and the challenge this implies in particular for the role of industry in a low-carbon economy. However, in the short run, the overarching aim is to protect European industry against a (perceived or real) threat of deindustrialisation. In this context, carbon leakage in particular is a very defensive policy, routed in a traditional understanding of industrial policy, and concerned above all with shielding energy-intensive industries from policy-induced pressures to change. This leads to a perceived mismatch between the EU short-run industrial policy objectives, aiming to protect ailing industries from too rapid change, and the long-term decarbonisation agenda (Åhman and Nilsson 2015, 104). This is starting to change only slowly with the EU Commission's proposal for an Innovation Fund as part of the post-2020 design of the EU Emissions Trading Scheme.

[10] Such a dematerialisation would imply a drastic increase in resource efficiency – scholars have suggested that a factor of four or ten is both necessary and possible (Weizsäcker, Lovins, and Lovins 1997; Angrick, Burger, and Lehmann 2014). It would involve closing of material cycles towards a circular economy, product substitution towards more light-weight, more durable and repairable or reusable products, and new business models based on product usage or services rather than product ownership.

3 Forms and Channels of Carbon Leakage

Moving from the main theoretical discourses around carbon leakage to practical manifestations of carbon leakage in the global economy and on the part of individual sectors, the challenge of setting boundaries that constitute clear definitions often comes down to how relevant firms in those sectors are structured. Producers of emissions-intensive and relatively trade-exposed products – those potentially at risk of carbon leakage – vary considerably in terms of corporate structure, production practices, and position(s) on product value chains. Thus, the following conceptual categories of carbon leakage overlap to a certain extent in the way they play out in practice – the overlap is particularly strong between production and investment leakage.[11]

3.1 Production (Operational) Leakage

Operational leakage occurs where differences in the intensity of climate policies between two countries adds to production costs in the country with more ambitious policies, and as a result leads to falling production levels in this country. This results in declining exports, or increasing imports, of the good in question (or both), and therefore a loss of market shares both domestically and abroad (Reinaud 2008; Alexeeva-Talebi et al. 2012; Droege 2009; Marcu et al. 2013, 4). As an important distinction, operational leakage occurs within given production capacities – resulting in a lower utilisation of domestic capacities, and a higher utilisation of capacities abroad. As such, it is more likely to occur in the short to medium run, until capacities are adjusted (Sachverständigenrat für Umweltfragen 2016, 113).

Given relative geographic constraints on raw materials used in emission-intensive processes and the transport costs associated with many emission-intensive products[12] – not to mention location-contingent value chains and production sequences – such a case of producing the exact same good for the exact same market in two locations, only with different carbon costs, remains theoretical. However, the scenario of falling production in Europe – and, crucially, reducing the associated jobs – and being replaced by production in locations with lower carbon costs is the archetypal embodiment of the carbon leakage narrative. That it is the subject of much debate between industry and policymakers involved in the EU ETS is compounded by labour market concerns, which are typically politically volatile: policies which transfer production, employment, and taxable profits to other countries are inherently contentious.

One obvious consideration – which, however, has significant implications in practice – is that the potential relocation of production volumes between different locations depends on the capacity to do so. Ideally, all plants, irrespective of their location, would operate at their optimal rate of capacity utilisation. In the short run (i.e. without changes in the capacity), significant changes in production level only occur where there is slack, i.e. idle capacity. In other words – the more overcapacity there is in a market, the more flexibility there is for transfer of production volumes between different facilities. In boom times, when all existing plants operate at full capacity, there is limited scope for operational leakage – irrespective of the carbon price differentials.

[11] The following section does not consider some other phenomena that the literature sometimes refers to as "carbon leakage", such as in-country leakage that occurs at the boundary of an ETS's scope, or leakage through nested regulation (whereby overlapping climate policy tools reduce emissions in a sector covered by the ETS, and hence creating "leakage" to other sectors under the ETS). These cases, however, are the consequence of domestic policy design choices, but are not related to international differences in the ambition of climate policies.

[12] The cement industry is a case in point for transport costs reducing likelihood of leakage: the weight of the product renders its manufacture highly regionalized, especially given increased transport costs associated with high fuel prices, which in turn are not always the result of climate policy. Ryan (2012) argues that "transportation costs are the most significant factors in determining Portland cement markets" (p.4) and Allevi et al (2013) conclude that carbon leakage in the Italian cement industry depends more heavily on transportation costs than emission-price (p.24).

Assuming that domestic production capacities are owned by domestic businesses, and foreign capacities owned by foreign companies, one of the consequence of regulation-induced declines in domestic production volume is a loss of market share for domestic producers. In the short term, EU-based companies' stand to lose market share to non-European competitors whose operations are less exposed to emissions constraints and thus to overall carbon costs. Depending on how global the market for the product in question is, the loss of market share would be felt both in Europe's' export markets, as well as in the domestic market. Export markets, in principle, could also include third countries: for instance, European steelmakers might also experience more pressure from Chinese competitors when exporting to the US.

This raises the important question how to delineate the relevant market, for which the market share of domestic producers would then be assessed. For instance, sectors such as steel and cement have expanded massively in China over the last two decades – growth that was mostly fuelled by domestic demand, driven by massive infrastructure spending, urbanisation and industrialisation (Neuhoff, Acworth, Ancygier, et al. 2014; Turcea and Kalfagianni 2015). This massive expansion of demand was mostly met with domestic supply from Chinese firms. This contributed to the well-established fact that the European-produced cement and steel account for a much smaller share of total global output than they did in the past: in the case of steel, the EU currently accounts for 11% of global steel production, compared to about a quarter at the turn of the century (Bolscher et al. 2013, 24). But to assume a constant global market share for EU manufacturers over time would imply that EU manufacturers should have benefited in similar measure from the surge in demand in China (and other emerging economies). In other words, the construction boom in emerging economies ought to have been fuelled by vast imports of steel, concrete and other materials – which would be a very bold, if not unrealistic, premise.

A further conceptual complication stems from the fact that the firms accounting for the majority of product volume in the emissions-intense sectors in question (particularly metals production, chemicals or refining) are multinational conglomerates, which operate production facilities all over the world, and for which only the parent or holding company may be based in Europe.[13] This means that carbon leakage, where it occurs, may well occur between different facilities within the same company. A loss of market share from one of these companies to the other therefore is not necessarily evidence of carbon leakage, and in particular cannot be traced to carbon prices in European locations. In the same way, actual carbon leakage as declining production volume in European locations – if and where it occurs – might not even be reflected in a smaller market share for the parent company, if production volumes are merely shifted to another non-EU facility operated by the same company.

3.2 Investment Leakage

Investment leakage refers to an effect whereby, compared to a baseline with equally stringent climate policies, companies invest *more* in facilities in regions with a less stringent carbon constraint, and *less* in facilities located in carbon constrained regions (i.e. the EU) (Marcu et al. 2013, 4). Compared to operational leakage, investment leakage is a phenomenon that will play out in the longer term: the forces that lead to operational leakage (higher costs for domestic production, reduced competitiveness and loss of market share, production below the optimal utilisation rate) effectively also reduce the return on domestic investment, and make it (marginally) less attractive to invest at home. In the longer run, means that more investment will flow abroad – hence domestic capacities are lower than they otherwise would have been, and instead higher abroad (Sachverständigenrat für Umweltfragen 2016, 113).

[13] Multinationals Arcelor-Mittal and ThyssenKrupp – each with significant production holdings outside Europe – together account for more steel production in Germany than the next eight (German) steel companies combined. All of the top five European chemical companies by sales volume (BASF, LyondellBasell, INEOS, etc.) have significant holdings – especially primary production facilities – outside Europe, with some even officially headquartered outside Europe.

Likewise, investment leakage may also occur if foreign companies, who would otherwise have invested in Europe, decide to invest in other countries instead (reduction of foreign direct investment from third countries).

Yet any relocation scenario, in which entirely new facilities are built elsewhere, is at the extreme end of the spectrum of carbon leakage manifestations simply because (unlike firms in the service sector), aluminium smelters, steel mills, or nitrous oxide processors cannot "set up shop" in a new location quickly or cheaply. This is due to the sheer magnitude of physical infrastructure in the sectors involved, as well as their integration into global supply chains and complex logistics.

At least at an initial stage, investment leakage would presumably be subtler: firms would be reluctant to carry out maintenance, refurbishment or upgrades of their emissions-intensive infrastructure in Europe if they expect that the carbon cost would lower their return on such investments (Sachverständigenrat für Umweltfragen 2016, 113). In a more extreme investment leakage scenario, it would no longer be deemed profitable to invest in the EU, compared to jurisdictions with a laxer carbon constraint or none at all. The graduated nature of investment leakage goes back to the orders of magnitude of asset value at stake, where emissions-intensive activities involve enormous infrastructure investment per expected unit of revenue.

Investment leakage is of particular political concern, due to the importance of investment for the economic development: to begin with, investment is closely linked to employment, thus investment abroad is typically associated with job losses at home. Second, investment generates a future revenue stream – therefore also future economic welfare, tax revenues etc. depend on investment. This link is all the more prevalent in current circumstances, with an investment shortfall identified e.g. in Germany (Blazejczak et al. 2013). And third, investment leakage is basically irreversible within the economic lifespan of the plant – unlike operational leakage, which can be reversed if circumstances change.

In practice, of course, private companies' decisions on where to expand or reduce production capacity involve trade-offs between a broad range of factors. These include access to new markets for their product and the growth potential of those new markets, tax incentives at the foreign location, tariffs and other trade barriers, exchange rate risks, availability of qualified labour and relative wage levels, access to capital, proximity to suppliers, availability and costs of raw materials, electricity and other inputs, access to infrastructure, logistics and transport costs. In addition, factors related to the general investment climate, such as the ease of doing business, rule of law and protection from seizure or other interference, but also corruption and red tape (Sachverständigenrat für Umweltfragen 2016, 109; Aldy and Pizer 2011; Neuhoff, Acworth, Dechezleprêtre, et al. 2014). As mentioned above, the degree to which carbon constraints play a role in these decisions – and thus the degree to which an investment decision constitutes a case of carbon leakage – is difficult if not impossible to investigate empirically. This indeed points to a broader issue with the measurement of investment leakage: the need to define a counterfactual scenario, or a what-if-scenario: what would the investment decision have been, if there had not been any differences in the stringency of climate policies. Yet investment decisions are ultimately taken by individuals, and they necessarily involve an element of intuition and entrepreneurial spirit. Which makes it difficult to establish ex-post what role, if any, expectations about current and future climate policies have played in the decision.

A particular difficulty with investment leakage is to discern investment leakage from structural change to a low-carbon economy (see also 2.3.4). The EU has declared its ambition to drastically reduce its emissions (80-95% below 1990 levels by mid-century). Most of the technologies currently in use are far more emission intensive than what would be in line with these climate policy goals. Yet the economic lifetime of the physical assets in many energy-intensive industry sectors amounts to several decades. This means that investments into energy-intensive installations and infrastructure, using technologies that are currently dominant, involves a high risk of locking the EU onto a high-emission

trajectory. This, in turn, would lead the EU policy into a dilemma of either missing the decarbonisation targets, or leaving the domestic industry with stranded assets. Thus, reducing emission-intensive investments, irrespective of where they occur, is also a part of successful (and economically efficient) climate policy with a long-term orientation.

At the same time, reducing emission-intensive investments at home would not be a desirable outcome if these domestic investments were merely replaced by emission-intensive investments abroad. If the argument is based on the premise that there is a given demand for emission-intensive products, and that this demand will inevitably be supplied through the market, the argument is effectively framed as a zero-sum game. In this reading, emission-intensive investment will inevitably take place, and if unilateral, domestic climate policy discourages investment at home, then the same investment will simply occur abroad, meaning that unilateral climate policy leads to a loss in investment, jobs, and future earnings.

This leaves two competing perspectives on investment leakage: one maintains that it is desirable to reduce emission-intensive investments, in order to decarbonise the asset base and infrastructure. The other argues that such a move is self-damaging, because the investment will simply occur elsewhere – the domestic economy faces the cost of foregone returns and jobs, at no gain to the global environment.

Which of these two arguments is more convincing is a matter of judgement, which can be informed by, but not resolved through empirical analysis. For instance, the credibility of the latter position – that emission-intensive, high-fossil investment will always find a suitable investment location somewhere that is not carbon-constrained – is called into question in light of the Paris Agreement, in which 162 parties to the UNFCCC – representing 189 countries – submitted an "intended nationally determined contribution" as their contribution to achieving the aims of the Paris Agreement. While the collective level of ambition expressed in these NDCs is insufficient, and while it remains to be seen how stringently these pledges will be implemented, it is also clear that they do represent some kind of commitment to GHG mitigation, and hence some kind of carbon constraint. And even if the current climate and energy policy does not impose any constraints on the GHG emissions of new investments, it seems questionable at least whether an investor should assume that this will remain the case for the entire economic lifetime of the asset in question.[14] Here, the US under the Trump administration is a case in point: Trumps announcement on 1 June 2017 that the US would withdraw from the Paris Agreement would seem like an invitation to invest in energy- and emission-intensive installations in the US. And yet – Trump's announcement has also provoked backlash at the level of US states, cities and corporations,[15] and it is uncertain whether a future administration would revoke Trump's withdrawal and rejoin the Paris Agreement. And besides, an investor could face a reputational risk if he or she is seen to exploit what most Europeans consider a reckless and irresponsible move by the Trump administration.

3.3 Leakage through Resource Markets

A third channel through which carbon leakage may occur is through the interaction of climate policies and resource markets, in particular markets for fossil fuels. The causality works as follows: one effect of climate policy is to suppress demand for fossil fuels in one country or world region (by making it more expensive to burn fossil fuels, or by promoting alternative fuels). If this country accounts for a

[14] This point touches upon the interplay between the signals that the regulator sends to potential investors and the expectations that investors form, based on the signals received. Kuik (2014) provides an example that such signalling effects may lead to counterintuitive results: he argues that lower stringency of environmental regulation will only lead to higher investment to some extent. At some point, the relationship is reversed, as investors would interpret a too low environmental stringency as a signal of poor regulatory quality overall, which thus poses a risk for their investments (Kuik 2014, 38).

[15] See e.g. https://www.wearestillin.com/

large enough share of global demand (as may be assumed for the EU as a whole), and with fossil fuel supply unchanged, the result will be fossil fuel prices that are lower than they would be in the baseline. This has two results: first, it benefits fuel importers, as it lowers the rents of fossil fuel exporters (Branger and Quirion 2014, 4). But second, countries with less stringent climate policies in place will have an incentive to increase their consumption of fossil fuels compared to the baseline. To put it differently – the assumption is that fossil fuel supply is inelastic in the short run, meaning that fossil fuels will be produced anyway. If the EU does not import them, someone else will, and the price mechanism makes sure that the market clears.

Numerical estimations have shown that this channel of leakage through resource markets can indeed account for a substantial part of the overall leakage risk, potentially outstripping the leakage through the competitiveness channel (Böhringer, Fischer, and Rosendahl 2010; Böhringer, Rosendahl, and Schneider 2013; Branger and Quirion 2014).

However, whether the rationale holds depends on the assumptions made about the functioning of the international oil market, and about the behaviour of key actors. In a competitive market, falling demand in the EU would lead to falling prices, and hence rising demand abroad. Christoph Böhringer et al. point out that, while much of the empirical modelling suggests that leakage through international resource markets could be the dominant channel of carbon leakage, exceeding the competitiveness channel (operational and investment leakage), these models all assume perfectly competitive international oil markets, with oil producers as price takers (Böhringer, Rosendahl, and Schneider 2013, 4).

But the international oil market is not a perfect, competitive market. An alternative assumption about the functioning of the oil market is to view the OPEC group of countries acts as a supply-side oligopoly with the power to act as a swing producer (who can reduce or increase production at will), and thereby influence market prices. In this interpretation, if unilateral climate policy in the EU were to reduce oil demand, OPEC countries would respond by cutting supply, thereby keeping oil prices stable or even increasing them. In this way, a coordinated and effective response from OPEC – which maximises OPEC's rents from oil sales – could reduce leakage through international resource markets significantly, or even turn it negative. At any rate, leakage through the fossil fuel channel would be smaller than leakage through the competitiveness channel (Böhringer, Rosendahl, and Schneider 2013, 16).

A second hypothesis about oil producers' behaviour points into the opposite direction: when faced with the prospect of drastic policy-induced emission reductions or the emergence of alternative, low- or zero-carbon fuels, oil suppliers could seek to accelerate the exploitation of their resources and bring forward the sales of oils, in order to protect their revenues. This effect has been described as the "Green Paradox": fossil fuel consumption may increase as a direct, yet undesired consequence of ambitious climate policy (Gerlagh 2011; Jensen et al. 2015; Sinn 2008). The Green Paradox can also be understood as intertemporal leakage, in the sense that emissions leak from a more tightly regulated future, with a higher expected carbon price, to a less tightly regulated present with a lower carbon price. Confounding the effect is the risk of lock-in into fossil-intensive technologies: by intensifying the use of fossil fuels, it also delays the introduction of low-carbon alternatives, and increases their cost. In addition, this process may (or may not) also have a spatial dimension.

Again, as with the previous case of leakage through international resource market, while the argument itself is robust and intuitive, its practical validity depends on a number of assumptions. This concerns, for instance, the development of extraction cost of fossil fuel reserves as extraction increases in the present; it concerns capacity constraints, or it concerns the degree to which different types of fossil energy carriers, as well as renewable energies, can substitute each other. Much of the initial literature assumed constant extraction cost, perfect substitutability and no capacity constraints. Changing these to more conservative assumptions reduces the likelihood of the Green Paradox occurring, as well as the possible extent of the effect (Gerlagh 2011, 93; Jensen et al. 2015, 255).

3.4 Indirect Carbon Leakage

In addition to the previous concepts, another channel of carbon leakage is via second-order price effects. In a properly functioning ETS, not only will a carbon price apply to greenhouse gas emissions directly. Indirectly, there should also be an effect on the price of products that are carbon-intensive to produce (such as electricity, heat, steel or cement). As such, this price response is necessary to reap the full efficiency of a carbon market, as it distributes the reduction effort along the value chain, to use all available reduction options in the order of their economic efficiency.[16]

The fact that there are both a direct carbon price (imposed on actual greenhouse gas emitters) and an indirect carbon price (imposed on consumers of carbon-intensive products) means that, at least in theory, there can also be carbon leakage triggered through the indirect carbon price. If the carbon price increases the cost of electricity, this may influence the operational or investment decisions of industrial installations that use a lot of electricity, such as aluminium smelters. In EU ETS jargon, this phenomenon is commonly referred to as "indirect carbon leakage". The term is actually misleading – the leakage itself is not more or less direct than the "normal" operational and investment leakage, and certainly more direct than the leakage that occurs through international resource markets; it is rather the carbon price signal that is indirectly transmitted.

[16] Whether or not a price response is possible will depend on the market structure and the intensity of competition from foreign producers that do not face a carbon price. A common assumption is that full cost pass-through is possible for electricity and heat – where competition from non-EU suppliers into the EU is limited by the available, narrow interconnection capacity into the EU; and that no cost-pass through is possible for industrial outputs such as steel, cement or refined petrochemical products, since these are traded internationally and producers therefore have to take the world market prices as given. It remains debated whether this interpretation is indeed correct, since there is evidence that EU companies in the steel, refineries and petrochemical sectors are able to pass through part of their (opportunity) costs from the EU ETS by raising the prices of their products (de Bruyn et al. 2010; de Bruyn, Schep, and Cherif 2016).

4 Conclusions

The risk of carbon leakage is clear: in a world of uneven carbon prices, there will – ceteris paribus – be an incentive to relocate production, and to shift investment in energy-intensive installations to regions with no or lower carbon prices. Compared to a baseline with equally stringent policies everywhere, this implies that together with production volumes, the associated emissions will shift abroad – as well as jobs, investments and profits. Although the outlook for global cooperation on climate policy has become more positive since the adoption of the Paris Agreement, and although the share of global emissions that is covered by a carbon price continues to grow, the resulting carbon prices are likely to remain uneven internationally for the foreseeable future, if not indefinitely.

However, after more than a decade of research on carbon leakage induced by unilateral climate policies – and three decades of research on the relation between environmental regulation, firm competitiveness and investment decisions more broadly – several question marks remain all along the causal chain that describes carbon leakage.

- How strong is the leakage incentive from differences in carbon prices really? How strong has it been in the past, given the modest rates of carbon prices observed in Europe so far, and the relief measures put in place against carbon leakage? And how strong could it become, given the tendencies in more and more emerging economies to establish a carbon price (or some other type of carbon constraint)?
- How strong is the incremental effect of carbon leakage in addition to the underlying trends – shifts in global demand, trends in commodity prices, structural change induced by technological change and / or by industrial policy?
- Are there still unregulated locations that investors would leak to – and how realistic is the expectation that they will remain unregulated over the time horizon of the investment? Will there still be pollution havens in 2030, and would these be interesting investment locations?
- If all potential carbon leakage target countries have some kind of climate policy commitment in place (be it an absolute or a relative emission reduction target, an economywide or a sectoral one) – to what extent can leakage from the EU still be said to lead to additional emissions in the carbon leakage target countries?
- In light of the transformation to a low-carbon economy in Europe and globally – is there still a realistic business case for firms defending their competitiveness by staying cheap and dirty? What could be a more adequate balance between the defensive leakage debate – aiming to shield domestic industries from the harmful side-effects of unilateral climate policy, but in the process neutralising the incentive to change – and the forward-looking debate on encouraging low-carbon innovation and structural change towards a low-carbon economy, and on the place of industry in this economy?

For some sectors, at some times, leakage could become a real threat to their continued operation in Europe. Yet for the time being, it appears that the risk of carbon leakage is not as big as it is made out to be, certainly in comparison to other changes in the marketplace, that are brought about by market liberalisation, technological change, changes in labour costs and other cost factors, or shifts in consumer demand (Bassi and Zenghelis 2014; de Bruyn, Schep, and Cherif 2016; Neuhoff, Acworth, Dechezleprêtre, et al. 2014; Bolscher et al. 2013). Going forward, the terms of the debate should change from protecting the losers to creating winners – designing industrial policies that encourage low-carbon innovation, and help EU industries to develop and defend a leading position in this global race.

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