INCLUSIVE FORUM **ON CARBON MITIGATION APPROACHES** PAPERS

Analysing the international spillovers of climate change mitigation policies

A methodological framework

OECD

Inclusive Forum on Carbon Mitigation Approaches Papers

Analysing the international spillovers of climate change mitigation policies

A methodological framework

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Inclusive Forum on Carbon Mitigation Approaches Papers

The IFCMA Papers series brings together outputs from the initiative's work to take stock of different carbon mitigation approaches, map policies to the emissions they cover, and estimate their impact on greenhouse gas emissions, as well as its work to analyse methodologies for computing the carbon intensity of goods and sectors. Comments on IFCMA Papers are welcome at IFCMA@oecd.org.

Background

The Inclusive Forum on Carbon Mitigation Approaches is the OECD's flagship initiative to help optimise the global impact of emissions reduction efforts around the world through better data and information sharing, evidence-based mutual learning, and inclusive multilateral dialogue.

By taking stock of different carbon mitigation approaches, mapping policies to the emissions they cover, and estimating their comparative impact in terms of emissions reductions, the IFCMA is enhancing understanding of the comparative impact of the full spectrum of carbon mitigation approaches deployed around the world and their combined global impact. The IFCMA is also identifying and addressing challenges related to the calculation of sector- and product-level carbon intensity metrics, relevant to the design and evaluation of mitigation policies, and to steer firms' and consumers' decisions towards lower-emission products. This work supports better international coordination to avoid the proliferation of different standards, help minimise compliance costs for business, and avoid disruptions to trade.

To advance its technical work, the IFCMA brings together delegates from the climate, tax, and structural economic policy communities from more than 60 IFCMA members and numerous countries participating as Invitees around the world.

Abstract

This report presents a methodological framework to analyse international spillovers from domestic climate mitigation policies—specifically economic, technology, and policy spillovers—and their impacts on global emissions and economic outcomes. These effects can be positive—such as accelerating low-carbon technology diffusion or the implementation of mitigation policy adoption abroad—or negative—such as shifting emissions across countries, i.e., carbon leakage, and fragmenting international markets. Advancing a shared understanding of international spillovers is essential to the IFCMA's objective of enhancing the global effectiveness of mitigation efforts. To this end, the report provides a typology of spillover effects and transmission channels, reviews tools available to analyse them, synthesises the existing evidence, and explores policy design and responses to manage spillovers. This framework forms the analytical foundation for the upcoming IFCMA work to deepen the evidence base and support more co-ordinated international climate action.

Keywords: Climate policy; international spillovers; carbon leakage; technology diffusion; policy diffusion; trade and competitiveness; carbon intensity

JEL codes: F18, F64, H23, Q43, Q48, Q54, Q55

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Executive summary

This report presents a methodological framework to guide a coherent and structured analysis of international spillovers arising from domestic climate change mitigation policies. International spillovers refer to cross-border economic, technology or policy effects arising from domestic mitigation policies, that impact global greenhouse gas (GHG) emissions and economic outcomes. They can be positive—such as accelerating diffusion of low-carbon technologies — or negative — such as giving rise to carbon leakage and trade distortions. Gaining better insights into these cross-border effects is a key enabler for international co-operation to maximise positive spillovers and minimise negative ones. To this end, this methodological framework provides a typology of different international spillovers and their transmission channels, reviews analytical tools and existing evidence, and highlights relevant responses to manage spillovers.

The main messages of the report are the following:

- **Domestic mitigation policies can lead to economic, technology, and policy spillovers affecting emissions and economic outcomes abroad.** These international spillovers, which often co-exist and interact with each other, can significantly influence the overall effectiveness of policies in achieving global emission reductions and other policy objectives. Their net impact on global GHG emissions and economic outcomes may evolve over time and depend on policy instrument and design choices across countries, specific country contexts, and the transmission channels involved, such as the cost and diffusion of low-carbon technologies and changes in energy prices.
- **Fragmented climate policy across countries may dampen positive spillovers and exacerbate negative ones.** Such fragmentation can increase the risk of competitiveness losses and carbon leakage, undermining policy effectiveness and discouraging climate mitigation action. Fragmented policy signals across countries also increase compliance costs for firms and make it harder for them to assess the viability of investments in research and development (R&D) in low-carbon technologies or scaling up low-carbon production capacity. This risks slowing down innovation and diffusion of low-carbon technologies.
- **Evolving mitigation policies, recent and projected technological developments and changing economic conditions call for an assessment of international spillovers that build on the strengths of different analytical tools.** Ex-ante models enable forward-looking assessments of policy impacts across countries, though they vary in their ability to capture technological and behavioural details. Ex-post econometric studies offer insights based on past data but may be less reliable in anticipating future outcomes, especially in case of large changes in mitigation policies, technological developments and economic conditions. Combining ex-ante and ex-post methods can enhance analytical rigor and improve the robustness of policy analyses.
- **Evidence shows that technology spillovers play a crucial role in accelerating low-carbon technology innovation and diffusion globally.** Ex-post evidence highlights that demand-pull and technology-push policies, i.e. policies that create demand for low-carbon goods and technologies, and support their development, can drive innovation and cost-reductions through, for instance,

learning-by-doing and economies of scale. However, such innovation is often concentrated in a few high-income countries. Foreign direct investment (FDI) and trade facilitate the diffusion of low-carbon technologies, highlighting the role trade and investment policies in generating positive spillovers.

- **Economic spillovers occur when mitigation policies affect competitiveness, trade and investment flows, with evidence pointing to varying effects across time and sectors.** In the short term, stricter mitigation policies, such as higher carbon prices, can raise costs for emission-intensive sectors. Yet, ex-post studies have reported modest aggregate competitiveness impacts, likely due to the limited stringency of the mitigation policies to date, also because of generous compensatory measures. Forward looking analysis based on ex -ante models simulating large policy changes instead suggest large economic spillovers from mitigation policies. Some mitigation policies can also facilitate the development of low-carbon goods markets and create new business opportunities. Evidence on the impacts of government support for firms in these markets is limited, however. Early studies suggest that while government support measures can contribute to cost-reductions, they also involve longer-term risks, such as increasing market concentration, crowding out efficient producers, and lower innovation incentives, depending on policy design.
- **Policy spillovers, i.e. when countries adjust their policies in response to the policy choices of others, can significantly influence the pace of global mitigation efforts.** Evidence suggests that countries acting as first movers – by adopting carbon pricing or measures to support renewable energy – a have played a pivotal role in encouraging others to adopt similar policies. Moreover, countries respond strategically to (the lack of) action in other countries to protect their competitiveness. This is reflected in the implementation of safeguard mechanisms in mitigation policies targeting energy-intensive trade-exposed (EITE) sectors, of subsidies schemes mirroring those in other countries, or of product standards of large trading partners to secure market access. Where such responses foster convergence towards more stringent policies, they can contribute positively to global emission reductions.
- **Evidence on how international spillovers impact global emission outcomes is limited and fragmented.** The impact of the shift of economic activities and associated emissions across borders due to asymmetries in mitigation policies across countries is the most extensively documented. Ex-ante studies estimate carbon leakage rates between 5% and 30%, reducing the effectiveness of domestic mitigation policy: for e.g. 100 tonnes of GHG emissions reduced domestically, emissions in the rest of the world increase by 5 to 30 tonnes. Most recent ex-post studies report leakage rates within this range. The evidence base on the impact of other economic spillovers, as well as technology and policy spillovers, on emission outcomes is limited, partially due to challenges related to data availability and the attribution of observed effects.
- **International spillovers' impact on economic outcomes such as gross domestic product (GDP) and employment are highly heterogeneous across countries and sectors.** Some fossil fuel exporters may face diversification challenges or negative impacts from declining fossil fuel demand due to a transition to renewable energy sources and electrification. Consistent with broader findings on carbon leakage, EITE sectors have not experienced significant negative impacts on profits or employment to date, but such eventualities may materialise as policy stringency rises and compensatory measures are phased out. At the same time, due to a combination of economies of scale and know-how, cost reductions of low-carbon technologies and learning can foster comparative advantages in low-emission production processes in other countries, supporting investment and job creation build.
- **Jurisdictions' policy choices can impact international spillovers through a combination of domestic mitigation policies and internationally oriented measures**. Such policies influence emissions and economic outcomes through the three international spillovers (economic, technology, and policy spillovers). Their impact across different spillovers—whether intended or

unintended—varies significantly across these policies and how they are designed. Countries can attenuate or amplify certain spillovers through specific features of domestic mitigation policies (e.g. free allowances under emission trading schemes (ETSs) or preferential tax rates within carbon pricing schemes), by adopting a combination of policy instruments (e.g. a carbon intensity-based regulation for industrial firms may be combined with direct subsidies for emerging technologies, which would make the whole policy combination more budget neutral for firms) or by adopting internationally oriented measures. These can act as complementary instruments and may take the form of unilateral policies that also cover foreign emissions (e.g., border carbon adjustments) or of international co-operation agreements or policies.

Further analytical work by the IFCMA can fill crucial knowledge gaps in our understanding of spillovers. The IFCMA can help fill this gap by using the OECD's computable general equilibrium model 'ENV-Linkages' together with other models such as the World Induced Technical Change Hybrid (WITCH) model, and supported by empirical research and qualitative analyses. The methodological framework presented in this report charts the necessary steps to make such analysis possible.

1. Introduction

International spillovers related to climate change mitigation policies refer to economic, technology, or policy effects of domestic climate change mitigation policies on other countries. They arise because of countries' international linkages via global trade and because domestic policies interact with other countries' policy choices. These linkages and interactions influence variables such as relative production costs, prices, and innovation, shaping emission and economic outcomes across countries. International spillovers from mitigation policies could be positive—when they facilitate the adoption of low-carbon technologies globally and the diffusion of more ambitious policies—or negative—where they shift economic activity and emissions to jurisdictions with more carbon-intensive production or lead to international markets' fragmentation.

Developing a common understanding on mitigation policies' international spillovers can help advance the IFCMA's objective of optimising the global impact of emission reduction efforts around the world. This is especially important given the diversity in mitigation policy approaches across countries. Such diversity is consistent with the Paris Agreement's bottom-up approach and reflects the need for policies tailored to specific national circumstances and respective capabilities. Yet, it may also increase the potential for international spillovers. Greater insights into the nature and impact of spillovers, and their transmission channels, is a key enabler to unlock international co-operation in this area and develop solutions to maximise positive spillovers while minimising negative ones. Ultimately, a better and more structured understanding of these issues can provide a basis for more coherent policy-making across countries, strengthening the effectiveness of global climate action.

To this end, this paper proposes a methodological framework for a coherent and structured analysis of spillovers. It builds on a range of recent OECD work and contributions, including the joint report on "Working together for better climate action" from the Joint Task Force on Climate Action, Carbon Pricing, and Policy Spillovers (OECD et al., 2024[1]), the summary report of the Climate Club's 2024 Strategic Dialogues (OECD/Climate Club, 2024[2]) and the report "Navigating the trade-climate nexus: opportunities, challenges and policy options" (OECD, forthcoming[3]). This paper is organised as follows:

- Section 2. provides a typology that distinguishes between types of international spillovers—namely, technology, economic, and policy spillovers—and their transmission channel (e.g. changes in relative costs and in trade and investment patterns; peer learning); moreover, it identifies their impacts on two main outcomes of interest, namely global emissions and economic outcomes.
- Section 3. reviews the tools to analyse spillover effects and assess the relative importance of transmission channels; it summarises the existing evidence on international spillovers and their overall impact on emission and economic outcomes.
- Section 4. outlines options available to policymakers to amplify or attenuate international spillovers.

Analyses based on the methodological framework presented in this paper can provide policymakers with novel and robust insights into international spillovers arising from different mitigation policy choices. The literature reviewed for this framework reveals a fragmented body of work that focuses on selected spillovers and transmission channels and concentrates on specific regions and time horizons. Overcoming these limitations requires investigating the design and choices of policy instruments by IFCMA and partner countries by means of a coherent and comprehensive approach that relies on multi-regional, multi-sectoral dynamic computable general equilibrium (CGE) modelling analyses, supported by data, empirical investigations, and qualitative analyses. That is what the methodological framework put forward in this paper aims to enable. The final goal is to quantify the strength and speed of different spillovers effects, assess the relative importance of transmission channels through which spillover effects take place, and ultimately to quantify their impacts on global emissions and economic growth (or social welfare), i.e. the main outcome variables. A better and more structured understanding of these issues is key to informing policy responses and reinforce international dialogues aiming at amplifying positive spillovers while minimising negative ones.

2. A typology of international spillovers

Main messages

This section provides a typology of international spillovers. Its main messages are:

- **Domestic mitigation policies can have cross-border economic, technology and policy effects ("international spillovers") which ultimately affect emission and economic outcomes**. While analytically distinct, these spillovers are interlinked.
- **Technology spillovers arise when mitigation policies accelerate the cross-border diffusion of low carbon technologies and further encourage their development.** Demand-pull and technology-push policies – or more generally demand-side and supply-side policies – which respectively create demand for low-carbon goods and support their development, can help induce innovation and learning, leading to cost reductions for low-carbon technologies, and accelerate technology diffusion. Trade and foreign direct investment (FDI) are key channels through which these technologies can diffuse globally.
- **Economic spillovers arise from the impact of mitigation policies on economic variables such as production, trade, and investment.** In the short run, some mitigation policies may raise costs and reduce competitiveness of domestic firms, especially in targeted emission-intensive and trade-exposed (EITE) sectors. Over time, mitigation policies may also create opportunities for firms in nascent and expanding markets for low-carbon goods and services. Government support could help mitigate competitiveness risks in EITE sectors and boost competitiveness of firms in markets for low-carbon technology goods and services. Mitigation policies may also reduce domestic fuel demand, which could lower international fossil fuel prices and increase their demand abroad.
- **Policy spillovers occur when one jurisdiction's mitigation policy choices shape those of others.** Emulation through norm diffusion and peer learning, and strategic responses to emission or economic outcomes can raise mitigation policy ambition and lead to greater international alignment, but potentially also tit-for-tat dynamics, such as subsidy races.
- **Emission outcomes of international spillovers refer to changes in global or regional greenhouse gas (GHG) emissions.** Spillovers can ultimately lead to either higher or lower foreign emissions (i.e. positive or negative carbon leakage), affecting the geographical distribution of GHG emissions. As a result, global emissions may rise or fall.
- **International spillovers can also affect economic outcomes such as growth, income distribution, and social welfare more generally.** For instance, fossil fuel exporting countries could face diversification challenges to sustain growth and safeguard social welfare gains achieved so far, while other economies with large natural endowments of critical materials that are key to low-carbon technologies may benefit from new growth opportunities. The

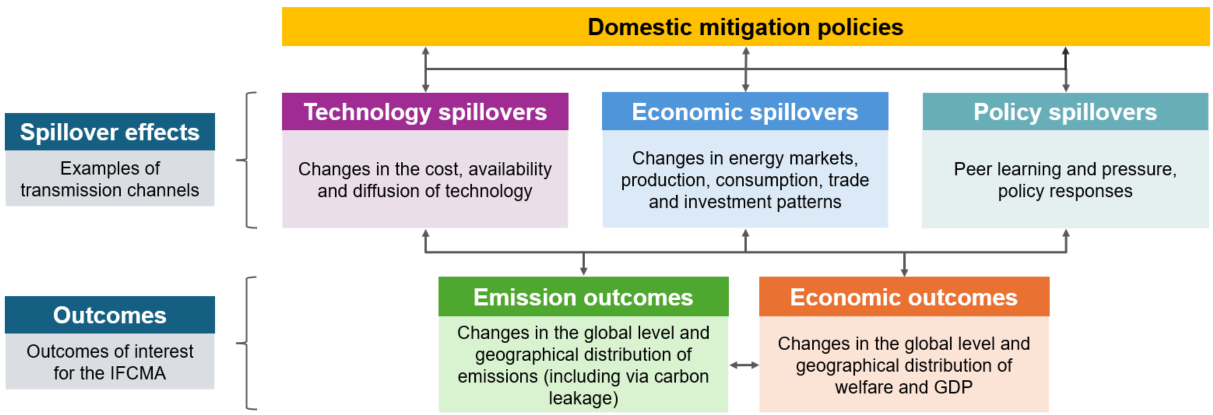
development and diffusion of low-carbon technologies could also shape industrial production and countries' sector specialisation, thus affecting economic growth.

- **The net global effect on emission and economic outcomes is driven by countries' circumstances and the relative strength of the different spillovers, which may change over time.** A better understanding of spillovers will help inform approaches to manage them.

2.1. Types of international spillovers and outcomes

Mitigation policies adopted in one jurisdiction can produce cross-border economic, technology and policy effects ("spillovers"), which ultimately affect global emission and economic outcomes. Economic spillovers arise from the impact of mitigation policies on economic variables such as production, trade, and investment. Technology spillovers arise when mitigation policies accelerate the cross-border diffusion of low carbon technologies and further encourage their development. Policy spillovers occur when one jurisdiction's mitigation policy choices shape those of others. The methodology framework proposed in this section is organised around these three types of spillovers, their respective transmission channels, and their outcomes (Figure 1). Their effects are likely to materialise over different time horizons, meaning that their net effects on global emission or economic outcomes, such as welfare and economic growth, could change over time. Spillovers can also interact with one another, with one type acting as a transmission channel for other types (e.g. technology spillovers leading to economic spillovers and then affecting emission and economic outcomes).

Figure 1. Stylised overview of the spillover effects related to mitigation policies



Note: Domestic mitigation policies can trigger international technology, economic and policy spillovers that interact with one another and ultimately lead to changes in global emission (including via carbon leakage) and in economic outcomes such as welfare and GDP. Emission and economic outcomes can also influence each other.
Source: Authors

For example, mitigation policies that raise the cost of domestic carbon-intensive production can reduce a jurisdiction's comparative advantage in emission-intensive sectors, potentially resulting in production shifting abroad. This shift may alter trade and investment patterns (economic spillover) and ultimately lead to increased emissions in other jurisdictions—a phenomenon known as carbon leakage (emission outcome). At the same time, such policies can create incentives for low-carbon innovation, which can in turn help reduce the cost of low-carbon technologies in the longer-run and lead to increased technology diffusion globally (technology spillover).

Policies that support the development and deployment of low-carbon technologies can likewise help drive down their costs. Examples of such policies are research and development (R&D) subsidies and support for the deployment of renewable energies. Low-carbon technological advances can diffuse beyond borders, through trade and FDI for instance, lowering global low-carbon technology prices and making renewable deployment more viable elsewhere (technology spillover). This may encourage other countries to adopt more stringent mitigation policies or invest more heavily in renewables, amplifying global mitigation efforts (emission outcome). At the same time, policies that reduce costs for producers may also affect their scale of operation, since they could lead to lower emissions per unit of production but potentially higher emissions from larger production scale (emission outcome). Furthermore, foreign producers of low-carbon technologies may face stiffer competition from producers in the innovating country, affecting their own competitive positions (economic spillover). As countries observe these dynamics, they may adjust their own climate policies (policy spillover)—either to protect domestic industries or to align with global technological trends—further influencing emission and economic outcomes worldwide.

Fully teasing out how different policy instruments can affect the different types of spillovers requires a systematic analysis that is not yet readily available. As laid out above, and also apparent from the review of existing evidence in Section 3, the specific design of policies affects how they change the behaviour of firms and households, and thus how they are transmitted abroad through the various channels. For example, for a carbon pricing policy, the associated spillover effects can depend on how the revenues are distributed; for technology subsidies, they can depend on whether they are aimed at deployment or directly support producers. A full analysis of how various instruments lead to different spillovers and thus ultimately change emissions and economic outcomes abroad can be further explored as part of the IFCMA's planned analytical work and build on the IFCMA policy database**.**

The final emission and economic outcomes from international spillovers may also vary depending on the way they are transmitted and the characteristics of the countries involved. For instance, countries that trade heavily with the policy-implementing country may experience stronger economic impacts, such as shifts in competitiveness or investment flows. Low-income or developing countries may face challenges with absorbing technology spillovers from more advanced economies if they lack the institutional capacity or infrastructure to adopt new technologies effectively. Resource-rich countries may benefit from increased demand for materials critical to the green transition, such as lithium or rare earth elements, while fossil fuel exporting countries may see a decline in revenues. In terms of policy responses, some countries may emulate ambitious climate measures due to reputational or strategic considerations, while others may resist or delay action if they perceive the policies as undermining their economic interests. In short, the direction and magnitude of spillover effects and their net outcomes are highly context-dependent and shaped by a complex interplay of multiple factors, including trade linkages, development status, industrial structure, natural resource endowment, and political economy considerations.

2.2. Spillover effects and their transmission channels

2.2.1. Technology spillovers

Mitigation policy can induce technology spillovers – i.e. the cross-border diffusion and development of low carbon technologies. This can occur by supporting the development, deployment and diffusion of low-carbon technologies domestically and abroad (Barker et al., 2007[4])**.** Policies encouraging the development and uptake of low-carbon technologies may be classified according to whether they encourage innovation or the diffusion of existing technologies or whether they affect demand or supply.

Demand-side policies, such as product standards, public procurement, deployment subsidies, can stimulate innovation, in addition to contributing to cost-reductions, by increasing the demand for

low-carbon goods and technologies and creating lead markets. Such policies, also referred to as demand-pull policies, can thus accelerate the international diffusion of foreign low-carbon technologies and products though imports and exports (if the origin of goods is unspecified in imports' eligibility requirements). Where trade barriers are low, growing demand for low-carbon goods and technologies in one country can also incentivise foreign firms to innovate in order to gain a foothold in that country (Peters et al., 2012[5]) – through channels including economies of scale and learning-by-doing. Product standards (e.g. fuel-efficiency standards), public procurement (e.g. green public procurement) and deployment subsidies (e.g. subsidies for the purchase of electric vehicles) can directly shape demand for low carbon goods. Carbon pricing may enhance demand for low-carbon goods through substitution effects. In the second order, it may also create incentives for innovation (see below).

Supply-side policies include technology-push policies that seek to enhance the supply of low-carbon technologies by reducing the private cost of their development (Nemet, 2009[6]; Nuñez-Jimenez et al., 2022[7]). For instance, tax incentives or subsidies for research and development (R&D) directly supports producers with the development of low-carbon technologies and production processes. Subsidies or tax incentives, particularly those targeted to early-stage technologies can accelerate innovation, drive down costs through learning-by-doing and knowledge spillovers, and support the global learning and diffusion of low-carbon solutions (Cervantes et al., 2023[8]; Dressler and Warwick, 2025[9]) – thus leading to technology spillovers.

Policies can support emerging technologies directly or indirectly and there may be feedback loops between demand-side and supply-side policies. For instance, R&D subsidies for green technologies discussed above support emerging technologies directly whereas carbon pricing may do so indirectly (through second order effects, i.e. dynamic efficiency gains) . For instance, the "Porter hypothesis" (Porter and Linde, 1995[10]), suggests that more stringent environmental policies can incentivise firms to maintain their competitiveness by improving productivity through investment in low-emission technologies and production processes. This example shows a close link between technology and economic spillovers through the impact on competitiveness. Indeed, evidence suggests that while regulations induce innovation in clean technologies, the resulting benefits do not appear to be large enough to outweigh the costs of regulations for the regulated entities (Dechezleprêtre and Sato, 2017[11]).

One channel through which mitigation policies induce technology spillovers operates through international trade in goods (Coe and Helpman, 1995[12]; Keller, 2004[13]; Melitz and Redding, 2021[14]). As demand for low-carbon goods and technologies increases and firms innovate, the costs of emerging low-carbon technologies tend to decline over time. Thus, international trade can provide access to foreign cost-efficient low-carbon technologies. In this way, domestic policy efforts or market shifts that expand demand for low-carbon technologies can generate positive spillovers through global supply chains—enhancing both the diffusion and further development of low-carbon technologies across borders (Peters et al., 2012[5]). Empirical evidence suggests that the adoption of demand policies is followed by a significant increase in imports of foreign low-carbon technologies into the policy-adopting country. By contrast, supply policies, do not exhibit the same pattern of increased foreign technology inflows (Peters et al., 2012[5]; Fabrizio, Poczter and Zelner, 2017[15]).

Another channel of international technology diffusion concerns foreign direct investment (FDI). Through FDI, domestic firms transfer firm-specific technologies and production processes and facilitate the transfer of related knowledge and skills to local firms and suppliers. This can strengthen local innovation and adoption capacities (Keller, 2010[16]; Bloom, Schankerman and Van Reenen, 2013[17]; Lu, Tao and Zhu, 2017[18]). The magnitude of these spillovers, however, depends on the host-country capacity to assimilate and effectively use foreign technologies (i.e. absorptive capacity), which is determined by factors such the level of human capital, the strength of domestic innovation systems and the protection of intellectual property rights (Javorcik, 2004[19]; Keller, 2004[13]; Cohen and Levinthal, 1990[20]). Such barriers might significantly hinder the transfer of patented inventions and the ease of knowledge diffusion (Dechezleprêtre, Glachant and Ménière, 2012[21]). FDI thus plays a dual role—serving both as a channel for international technology diffusion and as a complement to domestic policies that enhance local firms' ability to adopt imported low-carbon knowledge (Dechezleprêtre, Glachant and Ménière, 2008[22]).

A third channel of international diffusion is licensing, whereby a firm grants foreign companies the right to use its technologies to upgrade their own production processes. Evidence suggests that domestic environmental policies might induce innovation activity abroad, as firms respond by adopting licensed foreign technologies rather than relying solely on domestic innovation (Brunel, 2019[23]).

2.2.2. Economic spillovers

Variation in mitigation policies across countries can influence differences in firms' production and investment costs, with implications on competitiveness and international trade. Stringent mitigation policies (e.g. high carbon prices or strict regulations) can raise firms' production and investment costs due to higher energy and input prices, and compliance costs. As a result, firms may become less competitive than firms in jurisdictions with less stringent mitigation policies. In the short term, a loss in competitiveness induced by mitigation policies might result in reduced domestic output being replaced by an increase in imports (Aldy and Pizer, 2015[24]). In the long term, by increasing firms' costs, domestic mitigation policy can lead to geographical shifts in production, through relocation of firms and production lines, increased investment and production abroad (De Beule, Schoubben and Struyfs, 2022[25]). In turn, this may also increase the competitiveness of foreign firms (Känzig, Marenz and Olbert, 2024[26]).

At the same time, mitigation policies can also drive structural changes that could positively impact the competitiveness of firms. As discussed in the previous subsection, demand-pull and technology-push policies can lead to innovation and ultimately optimisation of production processes. This can result in higher productivity of domestic firms, thus enhancing their competitiveness. Moreover, subsidies for the deployment of low-carbon technologies could directly decrease businesses' compliance costs to domestic mitigation policies, such as carbon pricing. Adoption of low-carbon technologies can then be a way to reduce emissions while limiting short-run downside competitiveness risks arising from variations in stringency of mitigation policies across jurisdictions. These support policies, however, have fiscal costs, and may result in windfall gains.

Low-carbon production subsidies and other forms of supply-side government support could help firms scale up production of low-carbon goods and technologies, but could lead to undesirable effects if not well-designed (OECD, 2024[27]; OECD, 2025[28])**.** Economies that have sufficient fiscal space—combined with solid infrastructure and a skilled workforce—may be better placed to support and reap the benefits of emerging low-carbon industries than others. While support could lead to technology spillovers with positive impacts on environmental outcomes, large-scale and prolonged support for certain industries could also lead to market distortions and crowding out international competitors, which in turn may curb innovation and undermine competitiveness of other regions (OECD, 2024[27]; OECD, 2025[28]; OECD, 2023[29]). However, this depends on the type of sector and country. For example, fiscal support policies have been found to increase new cross-border investment projects in capital-intensive sectors in capital-abundant countries (Ruta and Sztajerowska, 2025[30]).

Mitigation policy can also alter relative prices and terms of trade, leading to changes in income and consumption patterns (Cameron and Baudry, 2023[31]). For example, reduced demand for fossil fuels in jurisdictions with stringent mitigation policies could lead to a decrease in energy prices. This could however eventually prop up demand elsewhere (Saussay and Sato, 2024[32]; Daubanes, Henriet and Schubert, 2021[33]). Moreover, where policies affect market access or the relative price of goods—for example, based on their carbon intensity level—such policies may shift consumption towards low-carbon alternatives or less regulated goods. Depending on where these goods are produced, this shift may lead to changes in production domestically and abroad (Dubash, 2022[34]). Income effects of mitigation policy can also reduce real wages and reduce consumption, which may in turn influence consumption patterns (Karp, 2013[35]).

2.2.3. Policy spillovers

Policy spillovers occur when policy decisions in one jurisdiction influence policy decisions in other jurisdictions. There are a range of transmission channels through which policy spillovers manifest (Dobbin, Simmons and Garrett, 2007[36]; Braun and Gilardi, 2006[37]). In the context of mitigation policy, they can be categorised in two broad groups: (i) norm projection, peer pression and peer learning and (ii) policy responses to emission or economic outcomes (Table 1).

Table 1. Categorisation of international policy spillovers related to climate change mitigation

Transmission channels	Examples of impacts
Norm projection, peer pressure, and peer learning	• High-ambition mitigation policies shape perceptions of responsibility, encourage emulation, and exert reputational pressure. • Foreign jurisdictions adopt similar mitigation policies after observing and learning from successful implementation or effectiveness elsewhere.
Policy responses to emission or economic outcomes	• Policy responses, such as border carbon adjustments (BCAs), to mitigate carbon leakage risks due to asymmetrical stringency of mitigation efforts. • Adoption or alignment of policies in response to foreign regulations such as BCAs or product standards. • Adoption or alignment of policies. including as part of trade agreements.

Source: Authors.

The first involves the imitation of foreign policies, either because adopting such policies is perceived as an international norm, or because they are deemed to be successful policies. First movers can reshape global expectations of adequate climate action, prompting other jurisdictions to emulate their policies (Thisted and Thisted, 2020[38]; Finnemore and Sikkink, 1998[39]; Dobbin, Simmons and Garrett, 2007[36]). Climate diplomacy and peer pressure, for example through participation in processes under the UNFCCC and Paris Agreement, can contribute to these dynamics (Kammerer and Namhata, 2018[40]). The policy experience gained by first movers can furthermore help reduce uncertainty for other policy makers by offering insights on policy impacts, challenges, and political and practical feasibility, potentially leading to other jurisdictions adopting similar measures (Baldwin, Carley and Nicholson-Crotty, 2019[41]; Sean and Carley, 2015[42]; Dobbin, Simmons and Garrett, 2007[36]). International organisations, fora, and platforms can also facilitate the exchange of such information among policy makers, further contributing to the diffusion of mitigation policies (Kammerer and Namhata, 2018[40]; Thisted and Thisted, 2020[38]; Haas, 1992[43]).

The second category covers responses to emission and economic outcomes, which may prompt adjustments in policy design or the introduction of new policies. In global markets, jurisdictions tend to adjust their policy settings in response to the measures adopted by their trading partners and competitors (Dobbin, Simmons and Garrett, 2007[36]).This is especially relevant in the context of a fragmented mitigation policy landscape (see Box 2.1). Responses could include a jurisdiction mirroring the subsidy schemes of other jurisdictions to maintain competitiveness, but also adopting the more stringent policies of its trading partners to maintain market access (Evenett et al., 2024[44]; Vogel, 1997[45]; Bradford, 2015[46]).

Box 2.1. The impacts of policy fragmentation

Mitigation approaches vary across countries. This is in line with the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC) enshrined in the Paris Agreement. It enables countries to pursue shared climate ambitions while tailoring approaches to different starting points and domestic circumstances.

Nevertheless, differences in the pace and ambition of countries' mitigation policies can also pose several challenges. For example, where countries' mitigation policies diverge substantially, some countries may hesitate to increase domestic policy stringency due to concerns about negative economic spillovers such as competitiveness losses and resulting emission outcomes – e.g. carbon leakage (see e.g. (OECD/Climate Club, 2024[2]; Climate Club, 2024[47])), as well as free riding by less ambitious countries. This could undermine both the effectiveness and public acceptability of ambitious mitigation action and creates a risk that global ambition will be held back by fear of negative economic spillovers.

Moreover, divergence in regulatory standards can increase compliance burdens for globally operating firms and hinder innovation. When companies must comply with multiple divergent regulatory frameworks, the resulting complexity may increase compliance costs and slow down the diffusion of low-carbon solutions. Fragmented policy signals can also decrease certainty for investors and innovators. When policies vary widely across markets, it becomes harder to assess the viability of investments in R&D or production capacity. This can discourage innovation, delay cost reductions, and reduce the global pace of technology deployment.

2.3. Outcomes of interest

2.3.1. Emission outcomes

International spillovers ultimately affect the geographic distribution and level of global emissions. One key impact of spillovers on global and regional emissions is known as carbon leakage, whereby the introduction or intensification of domestic mitigation policies results in change in foreign emissions (OECD, 2020[48]; Fowlie and Reguant, 2018[49]; OECD/Climate Club, 2024[2]). This can arise through economic spillovers: where mitigation policies erode domestic firms' competitiveness, economic activity may shift abroad, increasing emissions elsewhere. Likewise, lower fossil-fuel prices, driven by reduced demand in countries with stringent policies, could also induce carbon leakage by incentivising higher consumption—and hence emissions—in other countries. The policy-induced decrease of domestic emissions can then come with an increase in foreign emissions. Whether overall this results in higher or lower global emissions is an empirical question (see Section 3.).

Conversely, certain economic, technology and policy spillovers could also reduce global emissions. Economic spillovers lower global emissions when mitigation policies enhance the competitiveness of lower-carbon producers, expanding their market share domestically and internationally, for example through subsidies for low-carbon production or preferential treatment for low-carbon products. Technology spillovers that cut the costs of low-carbon technologies and bring innovations to market could accelerate global adoption, reducing emissions across countries. Finally, policy spillovers, where a mitigation measure in one country prompts others to follow, whether through learning, peer pressure effects, or competitiveness concerns, could also contribute to lower global emissions.

2.3.2. Economic outcomes

International spillovers can also influence economic outcomes through the multiple channels discussed above (OECD et al., 2024[1])**.** These outcomes include GDP, inflation, income distribution, employment effects, and economic costs of health externalities. The latter three may have also effects on aspects of social welfare that GDP and other standard economic indicators capture poorly.

Economic spillovers can have an impact on GDP growth and inflation. Stringent mitigation policies—especially when implemented by larger economies—might result in changes in supply and demand and affect international prices. For example, reduced demand and subsequently lower fossil fuel prices could boost GDP growth in importing countries. Conversely, countries heavily reliant on fossil fuel exports, could face reduced investment and revenue, and incur in job losses (NGFS, 2024[50]; Puyo et al., 2024[51]; IMF, 2022[52]). Moreover, for EITE industries, reduced competitiveness due to compliance costs of stringent domestic policies that are not offset by productivity gains, may translate into declining market share and investment, negatively affecting growth and jobs domestically.

Countries that export low-carbon technologies or critical minerals may experience higher growth due to increased demand (Hund et al., 2023[53]). Those integrated into green supply chains, such as manufacturing components for solar panels or electric vehicles, may see increased investment, output, and job creation (World Bank, 2023[54]). Yet, access to these opportunities may be unequally distributed across countries; as highlighted before, those with greater access to capital, a skilled work force and existing industrial base, are better positioned to capture economic benefits from the transition to net-zero emissions, in addition to countries with large endowments of critical minerals. For example, while trade-related climate measures adopted by major economies can incentivise shifts to less carbon-intensive production, they can also impose additional burdens on jurisdictions with more limited financial, administrative and technical capacities, potentially restricting their access to international markets and affecting their prospects for growth and development (Eicke et al., 2021[55]; Magacho, Espagne and Godin, 2023[56]).

Nevertheless, greater access to low-carbon technologies through technology spillovers could boost productivity and growth across countries. In the short term, lower costs of low-carbon technologies can spur increased investment in energy and industrial capital, which could support GDP growth and jobs creation in deployment and operations (OECD/UNDP, 2025[57]). Over the long-run, greater deployment can also raise productivity by decreasing energy costs and increasing energy efficiency of operations. It could also allow countries exploit comparative advantages—such as high potential for renewable energy generation—to compete in low-emission value chains (Pérez-Hernández, Montiel-Hernández and Salazar-Hernández, 2025[58]).

International spillovers can also affect climate risks, air quality and biodiversity, with implications for economic outcomes.. Reduced climate risks (de Serres and Murtin, 2011[59]; Millner, 2013[60]) and enhanced global air quality (Lanzi and Dellink, 2019[61]) can generate direct economic effects, which can be captured through metrics such as the value of a statistical life and the value of life years lost (Alberini et al., 2016[62]). Overall, several studies show that the economic returns of mitigating climate change—through avoided damages and enhanced resilience—far exceed the upfront costs of mitigation measures (Calvin et al., 2023[63]; OECD, 2017[64]; NGFS, 2022[65]; Kotz, Levermann and Wenz, 2024[66]; OECD, 2015[67]). In contrast, delaying global mitigation action leads to escalating physical damages, health costs, and productivity losses (Sanderson and O'Neill, 2020[68]), particularly for low- and middle-income countries (World Bank, 2024[69]).

3. Analysing international spillovers: analytical tools and evidence

Main messages

This section provides a succinct review of the analytical tools and of the literature quantifying international spillovers. Its main messages are:

- **A broad set of tools is available to analyse international spillovers.** Ex-ante approaches, including CGE models, are widely used for forward-looking analysis, as they capture economy-wide and cross-border interactions; ex-post studies instead estimate policy effects using past data. Both approaches have drawbacks. Ex-ante models consider often large and hypothetical policy changes (compared to actual policy changes recorded so far) to reflect the policy changes needed to meet long-term climate goals. They may also miss relevant features of the economy due to high levels of aggregation. Ex-post studies may underreport spillovers by focusing on specific channels while neglecting others due to lack of data or causal identification needs. In addition, empirical studies often fail to consider safeguards mechanisms (e.g. free allowances in ETSs). Combining ex-ante and ex-post approaches can help to overcome these drawbacks, enhance analytical rigour and the robustness of policy analyses.
- **Both demand-pull and technology-push policies foster low-carbon innovation and technology diffusion.** Yet, innovation remains concentrated in a few countries due to path dependency, cumulative expertise and economies of scale. Trade and FDI are central channels for accelerating diffusion, with intellectual property protections, collaboration programmes and multilateral initiatives further supporting international technology transfer.
- **Ex-post evidence suggests that, to date, factors such as labour and capital costs, and productivity levels have been more important determinants of firms' international competitiveness than mitigation policies.** This may be attributable to modest policy stringency or the use of safeguards to protect firms, so far.
- **Evidence on the effectiveness of government support for low-carbon industries is limited**. Initial evidence points to potential longer-term risks, if such support is not well-designed, such as market concentration, crowding out efficient producers that do not enjoy government support, or diminished incentives for innovation,.
- **Evidence suggests that first movers in mitigation policies have encouraged other countries to adopt similar policies, such as carbon pricing and support for renewables.** Available evidence also suggests that countries' reactions to other countries' mitigation policies also include adopting policies of large trading partners to maintain market access and mirroring subsidy schemes.

- **Evidence on the impact of spillovers on global emissions remains fragmented.** Carbon leakage is the most studied type of spillovers, with ex-ante estimates ranging from 5 to 30% and most recent ex-post studies' findings falling within this range. In contrast, evidence on other forms of spillovers – technology and policy spillovers – is still limited to data constraints and problems in attributing observed effects. Nonetheless, existing studies underscores the potential significance of these spillovers for global emissions.
- **Evidence on the impact of international spillovers on economic outcomes suggests highly heterogeneous across countries and sectors**. Fossil fuel exporters may face losses from declining global demand while EITE sectors may see pressure on profits and employment as mitigation policy stringency rises and safeguards are phased out. At the same time, while the development of low-carbon technologies is geographically concentrated, access to affordable low-carbon technologies can stimulate production, investment and employment in low-carbon sectors across borders, fostering new comparative advantages in these sectors.

This section reviews the main analytical tools used to assess international spillovers and the available evidence to date. Section 3.1 focus on available methodologies. It distinguishes between ex-ante modelling approaches and ex-post empirical analyses, and outlines their respective strengths and limitations. Section 3.2 summarises the evidence on spillovers and their transmission channels, structuring the discussion around technology, economic and policy spillovers. Section 3.3 then examines how these spillovers translate into emissions and economic outcomes.

3.1. Analytical tools for assessing international spillovers

Several tools are available to assess the existence, direction, and magnitude of international spillovers resulting from domestic climate policy. These range from quantitative methods—such as general or partial equilibrium (ex-ante) models, econometric (ex-post) models, network models and input-output analysis—to qualitative approaches, including case studies and policy analysis. These tools offer complementary insights. While quantitative tools can identify and quantify the scale and transmission channels of spillovers, qualitative assessments help contextualise their effects by capturing institutional and country-specific factors that may not be easily quantified. This subsection provides an overview, albeit not exhaustive, of the available analytical tools for assessing spillovers that the IFCMA' workstream on spillovers could rely on, with an emphasis on the quantitative methods.

The two primary methodologies to study international spillovers are ex-ante and ex-post assessments, which provide complementary insights. Ex-ante estimates are forward-looking. They are based on modelling and simulations allowing for projecting the potential spillovers under different policy and economic scenarios. In contrast, ex-post studies, and more specifically econometric approaches, analyse historical data to identify the spillovers that have already occurred due to past and present policies.

Computable General Equilibrium (CGE) models are one type of ex-ante models used to analyse spillovers. CGE models are well-suited for evaluating the mid- to long-term international spillovers effects of mitigation policies, as they capture dynamic interactions between a range of variables, including climate policy, prices and quantities of inputs and outputs across sectors and jurisdictions. CGE models can describe interactions between economic agents (i.e. different firms and consumers) within and between countries though intersectoral and international linkages. They are especially suited for investigating economic and emission outcomes as they take into account the effects of all transactions among economic agents in a consistent fashion. Among the different spillovers and transmission channels, the trade channel has been well examined, whereas the technology spillovers remains less studied (Cameron and Baudry, 2023[31]), partly because of the difficulties in capturing in a general equilibrium setting the rich set of technology details that such analyses require. CGE models tend to lack the technology details required for in-depth assessments of technology spillovers. Despite this limitation, they can replicate the insights from technology-rich models or empirical assessments to deliver estimates of the effects of technology spillovers in a general equilibrium setting.

A main limitation of CGE models is their dependency on key input parameters and assumptions, as well as limited heterogeneity across economic agents (firms within the same sector, households, etc.). They rely on a number of strong assumptions, e.g. elasticities, that describe the change in behaviour in response to a price or quantity shocks. CGE models are typically quantified (or calibrated) using out-of-sample econometric estimates or ad hoc methods. Thus, better data and empirical estimates can improve the quality of the ex-ante modelling. One example is technology spillovers as noted above. CGE models tend to have an aggregated description of technology learning effects and limited representation of specific technologies. Improved estimates of how mitigation policy affects the cost of different technologies can then improve the representation of the penetration of these technologies in the economy and result in better assessments of domestic and international technology choices and thus of emissions.

Some CGE models incorporate endogenous technological change in a tractable way. The WITCH model which is a hybrid CGE and Integrated Assessment Models (IAM) model, describes endogenous technology developments in a stylised way (Bosetti et al., 2011[70]). A recent example, Witajewski-Baltvilks (2025[71]) develops a recursive-dynamic CGE model in which technology firms optimise their R&D investment in response to market conditions, determining both the pace and direction of technological change. This approach allows the model to capture key innovation dynamics such as learning-by-researching, knowledge spillovers, and path dependency, as well as improving the long-run responsiveness of technology adoption to policy changes, particularly in low-carbon sectors. Witajewski-Baltvilks (2025[71]) studies a single economy only, and extending this to a global context is very challenging in terms of data requirements.

Integrated Assessment Models (IAMs), are another type of ex-ante model. They add feedback links from climate change to the socioeconomic drivers and tend to include significant technology detail, but often at the expense of a more stylised description of sectoral economic activity, consumption and government representation (Pirani et al., 2024[72]; van de Ven et al., 2023[73]; Riahi et al., 2017[74]). The bridge between CGEs and IAMs is fluid, and the two model types can be integrated.

Sectoral models, including partial equilibrium models, can also estimate the impact of mitigation policy on cross-border outcomes. The narrow focus of sectoral models allows for capturing specific technology choices and details. These analyses can be especially useful in sectors requiring a detailed description of technology choices and production methods, e.g. energy-intensive sectors, agriculture and land use. However, their crude representation of international economic linkages limits their ability to capture satisfactorily international spillovers compared to CGE models.

In addition to providing a basis for calibration, historical data and empirical (i.e. ex-post) analyses can complement ex-ante approaches. Ex-post studies rely on real-world data to identify patterns, causal relationships, and quantify the actual impacts of implemented policies, using more granular data, at the firm, plant and product level. Ex-post studies can assess the historical effectiveness of mitigation policies, their impacts on economic sectors, emissions and the real-world occurrence (or lack thereof) of international spillovers. However, the availability and quality of historical data can be a severe constraint for ex-post studies, sometimes preventing the reliable identification of causal effects of policies on national and foreign emissions. Isolating the specific impacts of a single policy change is also challenging due to the complexity of economic systems. Furthermore, historical data may not be a reliable predictor of future outcomes, especially when prospective policy changes are significantly larger than those experienced in the past or under rapid technology and institutional changes.

Combining ex-ante and ex-post approaches can offer a viable way forward that exploits their respective strengths while offsetting their limitations. Ex-ante analyses are key to projecting the relative importance of the transmission channels through which policies affect emissions and other outcomes, and to assess the interlinkages between the various effects. Ex-post studies can provide data and insights to calibrate, validate and further enrich ex-ante models. Estimated historical relationships and the magnitudes of past impacts can inform the parameters and assumptions used in ex-ante simulations. Distributions of emissions and economic outcomes derived from microdata (such as the distribution of plant-level carbon intensity or the type of technologies used) could enrich ex-ante models by providing insights on how different types of plants will react to policy changes and this will impact general equilibrium effects.

3.2. Evidence on spillovers and their transmission channels

3.2.1. Evidence on technology spillovers

Technology spillovers have been widely studied over the past decade. Studies have focused on the potential of mitigation policies to induce innovation in low-carbon technologies and to accelerate the diffusion through trade, FDI, and international co-operation.

There is robust evidence showing that demand-pull policies can induce low-carbon technology innovation. Firms' perception of weak demand or market uncertainty for new low-carbon technologies can significantly discourage decisions to pursue R&D for these technologies (García-Quevedo, Pellegrino and Savona, 2016[75]; Jaffe, Newell and Stavins, 2005[76]). Studies using a range of methodologies – including empirical analysis on the relation between demand-pull policies and innovation activities as measured in patent filings, (Johnstone, Haščič and Popp, 2009[77]; Costantini, Crespi and Palma, 2017[78]; Hille, Althammer and Diederich, 2020[79])[1] and qualitative analyses on technological innovation systems (Huang et al., 2016[80]; Quitzow, 2015[81]; Hansen et al., 2019[82]) – indicate that demand-pull instruments can help overcome innovation barriers. Nevertheless, evidence on which policies are the most effective and how they affect technologies across different stages of development remains heterogeneous (Hille, Althammer and Diederich, 2020[79]).

Studies also find strong evidence of spillover effects whereby demand-pull instruments can spur innovation abroad. A well-documented example is Germany’s adoption of feed-in tariffs for renewables in the 1990s and 2000s, which created a stable market for wind power and solar PV (Buchholz, Dippl and Eichenseer, 2019[83]; Böhringer et al., 2017[84]). Research shows these policies attracted major manufacturers to enter the market and encouraged innovation and cost reductions through learning-by-doing (see also Box 3.1) not only in Germany, but also in other countries, and particularly in the People’s Republic of China (hereafter ‘China’) (Huang et al., 2016[80]; Zhang and Gallagher, 2016[85]). Further evidence on spillover effects has been found for energy efficiency regulations (Kim and Brown, 2019[86]; Costantini, Crespi and Palma, 2017[78]), policy support for wind power (Choi, 2024[87]; Dechezleprêtre and Glachant, 2013[88]) and solar PV (Peters et al., 2012[5]), and environmental regulation more broadly (Khurshid et al., 2024[89]; Herman and Xiang, 2019[90]). Overall, Dechezleprêtre and Glachant (2013[88]) find that the aggregate impact of domestic demand-pull policies is larger on foreign than domestic innovation, pointing to the role of international trade links. Trade barriers in this respect may play an important role in moderating the innovation incentives for producers abroad and the global availability of affordable low-carbon technologies.

[1] A common obstacle faced by many of these studies is the lack of comparable data on the design of demand-pull policies across countries, making it challenging to compare the effects of different policies and policy designs—an issue that the IFCMA Climate Policy Database seeks to address.

In parallel, empirical evidence shows that technology-push policies encourage innovation domestically but not abroad. Such policies can overcome key barriers hindering innovation, such as high upfront costs and long-time horizons of basic research, as well as knowledge spillovers that prevent firms from fully capturing the returns on innovation (Jaffe, Newell and Stavins, 2005[76]). Numerous studies find that such policies—and in particular R&D support—can significantly increase patenting activity (Hille, Althammer and Diederich, 2020[79]; Johnstone, Haščič and Popp, 2009[77]) and are most effective when combined with complementary demand-pull measures in balanced policy mixes (Costantini, Crespi and Palma, 2017[78]; Lindman and Söderholm, 2016[91]; Nuñez-Jimenez et al., 2022[7]; Palage, Lundmark and Söderholm, 2018[92]). Yet these effects appear to remain confined within national borders (Kim and Brown, 2019[86]; Peters et al., 2012[5]), as such policies are likely to confer benefits directly to firms operating in the country, or some of them. At the same time, some studies caution that technology-push and government support can concentrate supply with ambivalent cross-border effects on foreign innovation (Aïd, Bahlali and Creti, 2023[93]).

Studies also highlight that the effectiveness of demand-pull and technology-push policies in fostering low-carbon technology innovation is dependent on a range of contextual factors. Patent data show that low-carbon technology innovation remains highly concentrated in a limited number of predominantly high-income countries (Probst et al., 2021[94]). This is consistent with empirical findings suggesting that innovation and specialisation in low-carbon technologies follow a cumulative, path-dependent trajectory, often building on existing expertise in related fields (Perruchas, Consoli and Barbieri, 2020[95]; Bontadini and Vona, 2023[96]; Aghion et al., 2016[97]) and general innovative capacity (Haščič et al., 2010[98]). Similarly, analysis of patent citation as a proxy for international knowledge spillovers suggests that, while the knowledge spillover for renewable technologies increased over time, it is higher among countries that have a comparable technological profile (Kim and Verdolini, 2023[99]). Evidence of diffusion of technology between high-income and low-income countries is still scarce.

Box 3.1. The impact of learning-by-doing and economies of scale in developing and producing low-carbon technologies

Learning-by-doing and economies of scale are key factors in reducing low-carbon technologies costs. Accumulated experience enables firms to optimise processes, enhance expertise, and improve technologies, which gives rise to a positive feedback loop of cost reductions, accelerated deployment, and further learning (Sagar and van der Zwaan, 2006[100]; IEA, 2020[101]). Numerous studies use a learning curve approach to estimate future cost reductions and quantify the size of learning effects (Glenk, Meier and Reichelstein, 2021[102]; Castrejon-Campos, Aye and Hui, 2022[103]). Under such an approach, technology costs are typically modelled as a function of cumulative deployment (i.e. cumulative production), which is used as a proxy for learning, although recent studies have started to incorporate a broader range of variables, such as R&D expenditures or scaling effects. These analyses generally support the relevance of learning effects, though some studies for solar PV highlight that economies of scale (i.e. production volume) may account for a larger share of cost reductions (Kavlak, McNerney and Trancik, 2018[104]; Yu, van Sark and Alsema, 2011[105]; Nemet, 2006[106]). This could however in part be the result of subsidy induced overcapacity (see Section 3.2.2 on economic spillovers below).

Demand-pull and technology-push policies can contribute to the emergence of lead markets, supporting learning-by-doing and scaling. Beise and Rennings (2005[107]) show that technologies generally only have achieved international success after initially gaining traction in a single national or regional market. Supportive policy environments help firms to experiment with different designs, scale up production, and demonstrate commercial viability in one region, with the resulting cost reductions facilitating further diffusion (Quitzow et al., 2014[108]). As first movers, firms operating in lead markets can build competitive advantages and capture significant global market share, although research finds these advantages can shift over time to other countries that have more supportive policies, lower cost bases or have higher market growth potential (Lacerda and Van den Bergh, 2014[109]; Horbach et al., 2014[110]). Even when technologies in lead markets fail to reach the economies of scale required for global adoption through market forces alone, these markets can inspire other countries to adopt similar policies—thereby indirectly promoting the broader diffusion of technologies (see section 3.2.3 on the evidence on policy spillovers) (Quitzow et al., 2014[108]).

The geographic concentration of innovation activities in few countries highlights the need to support low-carbon technology diffusion across borders. Open markets are key to this end. Research using patents and international trade data shows that trade is a key channel for the diffusion of low-carbon technologies by providing countries access to goods that embody these technologies (Pigato et al., 2020[111]; Glachant, 2013[112]; Dechezleprêtre and Glachant, 2013[88]). Over the past decade trade in low-carbon goods has accelerated significantly and accounted for approximately 30% of their global market value in 2023 (IEA, 2024[113]). The expertise of a limited number of countries in innovative, complex low-carbon technologies, such as wind turbines, drives international trade and enhance mitigation efforts in importing countries (Garsous and Worack, 2021[114]). Evidence also suggests that the implementation of new mitigation policies tends to contribute to the adoption of low-carbon technologies in the implementing country (Verdolini and Bosetti, 2017[115]). Pienknagura (2024[116]) shows this effect is stronger in low- and middle-income countries—which usually do not manufacture low-carbon technologies. Nevertheless, high-income countries still account for the majority of low-carbon technology imports (Gallagher et al., 2025[117]). Overall, this suggests that lowering trade barriers for low-carbon technologies could further increase the pace of their diffusion (IEA, 2024[113]; Pienknagura, 2024[116]; OECD, 2025[28]).

The role of FDI in the transfer of tacit knowledge of technologies depends on various factors. Evidence from China suggests that joint ventures are particularly effective in promoting technology diffusion to local firms (Liu, Lu and Yang, 2019[118]; Jiang et al., 2024[119]). At the same time, some studies have found that these arrangements cause foreign firms to bring only minimal technology to the host jurisdiction (Howell, 2018[120]). Overall, the extent to which technology spreads to domestic firms seems to strongly depend on the absorptive capacity of those firms (Cohen and Levinthal, 1990[20]), which in turn depends on existing local knowledge stocks and innovation capacity, as well as the quality of institutional and policy frameworks (Wang et al., 2022[121]; Amendolagine et al., 2023[122]; Qin et al., 2022[123]). For example, research shows that stronger protection and enforcement of intellectual property rights increase the likelihood of diffusion of low-carbon technologies (Dechezleprêtre, Glachant and Ménière, 2012[21]), including via licensing arrangements (Bosetti and Verdolini, 2013[124]). Factors such as employee mobility and commercial interactions between foreign and domestic firms can generally also play a role in knowledge diffusion (Ivarsson and Alvstam, 2005[125]; Fosfuri, Motta and Rønde, 2001[126]).

3.2.2. Evidence on economic spillovers

Economic spillovers encompass the repercussions of domestic mitigation policies on the economic variables that determine jurisdictions' international competitiveness. This in turn affects international trade patterns, FDI flows and the supply and demand of low- and high-carbon goods domestically and internationally. Climate policy is however only one of the many determinants of jurisdictions' competitiveness (Dechezleprêtre and Sato, 2017[11]).

Empirical evidence suggests mitigation policies have had so far a limited aggregate effect on competitiveness. The cost differential attributable to climate policy asymmetries across countries is dwarfed by other determinants of competitiveness, which affect input (including energy), labour and capital costs, and productivity. These determinants are varied and include, for instance, the efficiency of tax systems, the burden of regulations, the quantity and quality of infrastructure, R&D spending, in addition to many others. Specific analyses on carbon pricing (or higher fossil energy prices, which is a commonly used proxy metric for climate policy stringency) find only a modest impact on competitiveness (Venmans, Ellis and Nachtigall, 2020[127]). A systematic review of studies of policy instruments finds that the majority of studies report no trade-off between competitiveness and environmental objectives (Peñasco, Anadón and Verdolini, 2021[128]; OECD, 2021[129]). Indeed, over the past decade, policies have achieved environmental improvements with little aggregate impact on economic outcomes (OECD, 2021[129]).

Effects may vary however across firms, sectors, and time horizons. Stringent policies have generally a negative effect on highly-emitting industries (OECD, 2021[129]). Higher fossil energy prices, for instance due to carbon pricing, result in a modest increase in firms' investments in foreign jurisdictions (Saussay and Sato, 2024[32]). Although stringent policies do seem to lead to increased productivity—consistent with the Porter Hypothesis—the gains to date appear not to be large enough to outweigh the regulatory costs (Dechezleprêtre and Sato, 2017[11]). A more recent ex-post study by (Hasna et al., 2025[130]) suggests that low-carbon innovation supports economic growth primarily through capital accumulation in the medium term, while productivity gains are expected to emerge only over a longer horizon. Likewise, OECD/UNDP (2025[57]) shows, using an ex-ante model, that, under an enhanced NDC scenario, energy efficiency improvements and greater deployment of renewables translate into productivity gains. While electricity prices are projected to rise initially, they fall below those in a current-policies scenario over the longer term, with regional variation in the timing of these effects.

The empirical findings on limited adverse impacts of mitigation polices on aggregate competitiveness, to date, might stem from limited policy stringency in some countries or effective compensatory measures for affected firms in some others. Low carbon prices and safeguard measures, such as the allocation of free allowances in ETSs, exemptions, rebates and other measures, may have shielded firms— particularly those in EITE industries—from competitiveness losses. Findings from ex-post studies analysing these policies may therefore not provide a good picture of what might happen in the future if carbon prices rise, and safeguard mechanisms are phased out. In such circumstances, ex-ante assessments can provide valuable insights, complementing empirical studies. They can project the effect of future and large policy changes on countries' competitiveness, taking into account a rich set of sectoral and regional details that affect jurisdictions' competitiveness, namely input, labour and capital costs, and productivity developments.

Other transmission channels, including changes in international energy prices, may also generate economic spillovers. Ex-ante modelling studies provide consistent evidence in this direction. Most CGE models capture trade and competitiveness effects, as well as effects on international resource prices (including fossil fuels); thus, they generally capture the economic outcomes associated with the trade and energy market transmission channels. A recent literature review suggests that the trade channel—which works through competitiveness effects—and the international energy prices channel each account for about a third to half of total carbon leakage (Caron, 2022[131]). However, the trade channel is considered to be narrower than the international energy prices channel, as the effects of the former channel are limited to mainly EITE sectors (Böhringer et al., 2022[132]).

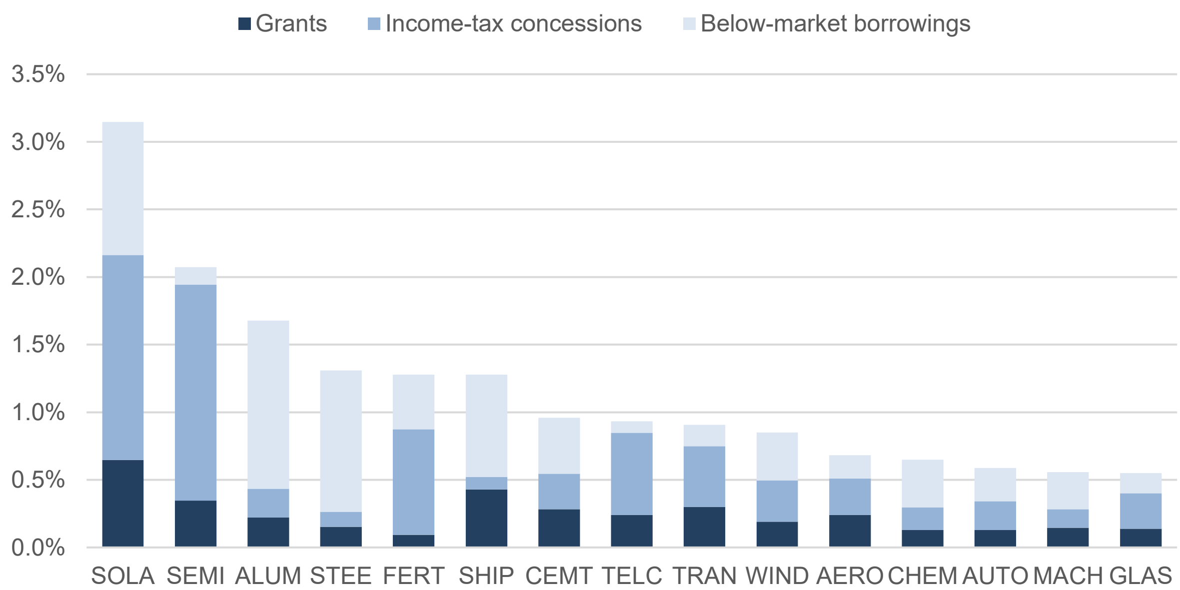
Finally, evidence on the competitiveness impacts of supply-side subsidies and other government support measures for low-carbon industries is scarce. Government support, which vary in form and complexity, is difficult to quantify due to absent or selective disclosure of key data by governments (OECD, 2023[29]). As a result, ex-post and ex-ante analyses on the impact of government support on trade and competitiveness remain limited (OECD, 2024[27]).

OECD work has sought to overcome several of these barriers, by collecting firm-level data from corporate disclosures. Such data shows that since 2005, solar PV manufacturers have been the largest beneficiaries of government support relative to their annual revenues (see Figure 2), with China-based producers until recently receiving the most support in both the solar and wind sectors (OECD, 2021[133]; OECD, 2025[134]). The OECD studies find that the substantial support received in the solar PV sector accounted for the notable increases in manufacturers' production capacity and the decrease in module prices. At the same time, these developments have raised concerns about excess capacity and eroding profit margins. This suggests that the observed decline in prices is not solely due to economies of scale and efficiency gains, but also to government support measures (OECD, 2025[134]). These findings are consistent with a recent OECD ex-post econometric analysis, showing that government support increases the market share of receiving firms, but seem to have at most a small effect on investment rates and no or a negative effect on real productivity growth (OECD, 2025[135]).

This evidence points towards potential negative economic spillovers of government support measures for competing firms in other jurisdictions. Key concerns relate to the concentration of supply, deterring competitors from making further investments, and crowding-out efficient firms in foreign countries (OECD, 2025[134]; OECD, 2025[135]). Thus, while government subsidies may lower prices and accelerate the diffusion of low-carbon technologies, market distortions they create may lead to other jurisdictions to respond with matching subsidies or trade restrictions (as discussed in the next section). These dynamics can lead to fiscally expensive subsidies races, ratcheting up of trade barriers, disruptions of global supply chains and ultimately to inefficient global production patterns.

Figure 2. Solar cells and modules were the most subsidised sector in the OECD MAGIC database between 2005 and 2023

Industrial subsidies by sector, average for 2005-23 (% of annual firm revenue)



Note: The data above are weighted averages by sector for the entire period 2005-23. SOLA = Solar photovoltaic cells & modules; ALUM = Aluminium; SEMI = Semiconductors; SHIP = Shipbuilding; STEE = Steel; CEMT = Cement & other building materials; TELC = Telecommunications network equipment; FERT = Fertiliser; TRAN = Rolling stock & signalling; WIND = Wind turbines; AERO = Aerospace & defence; CHEM = Chemicals; GLAS = Glass, ceramics & refractories.

Source: OECD MAGIC database.

3.2.3. Evidence on policy spillovers

There is a broad range of evidence demonstrating that mitigation policies spread through peer pressure and learning, and that jurisdictions adopt and adjust domestic policies in response to climate action in other jurisdictions. These studies often investigate the spread of a specific policy and employ a variety of methodologies, ranging from qualitative studies to use of CGE models and econometric analyses.

Evidence shows that emulation and peer learning are key drivers of the international diffusion of mitigation policies. For instance, Van Coppenolle (2025[136]) shows that leveraging peer networks could enhance global climate co-operation under the Paris Agreement and the Nationally Determined Contributions (NDCs) process, in particular for peer groups with high geopolitical affinity, similar levels of democracy, and regional similarity. Focusing on carbon pricing, qualitative analysis by Thisted and Thisted (2020[38]) demonstrates that early adopters of pricing instruments in Northern Europe encouraged wider uptake, and that international organisations supported this process by raising awareness on carbon pricing and promoting policy exchange. Similarly, Gulbrandsen, Sammut and Wettestad (2017[137]) document how the design of Kazakhstan's ETS drew heavily from the European Union (EU) ETS. Linsenmeier, Mohommad and Schwerhoff (2022[138]) provide empirical support, finding that the adoption of carbon pricing by neighbouring countries raises the likelihood of a country implementing similar measures by approximately 10% in a given year, which they attribute predominantly to emulation. Other studies have tried to isolate how different factors such as the structure of energy systems, political contexts (Baldwin, Carley and Nicholson-Crotty, 2019[41]) and implementation conditions (Sean and Carley, 2015[42]) can impact learning and emulation. Further research into these factors could enhance understanding of which policy instruments, design characteristics, and contextual conditions are most conducive to global mitigation policy diffusion.

There is also wide evidence that countries make policy decisions in response to carbon leakage and spillover risks. Empirical analysis by Dolphin and Pollitt (2021[139]) finds that reducing the risk of carbon leakage increases the likelihood that countries adopt pricing mechanisms. Among countries with existing pricing instruments, the free allocation of emission allowances for EITE sectors under ETSs and the recent implementation of EU Carbon Border Adjustment Mechanism (CBAM) are clear examples of policy action in response to leakage risks (Jakob, 2023[140]; Grubb et al., 2022[141]). Furthermore, numerous qualitative studies have shown how competitiveness concerns have influenced green industrial policies and in turn shaped policy responses abroad (Elkerbout et al., 2024[142]; Lewis, 2024[143]; Meckling, 2021[144]). Evenett et al. (2024[44]) provides recent empirical evidence of this dynamic, finding that on average, there is a 74% likelihood that a subsidy introduced by one major economy is matched by another for the same product within one year. In response to concerns about market distortions for solar PV and wind turbine supply chains, countries have also resorted to trade remedies, such as anti-dumping duties and countervailing duties, to level the playing-field (OECD, 2025[134]). These have increased significantly in recent years, from zero in 2011 to 35 in August 2024.

Market access is frequently cited to play a key role in the diffusion of more stringent mitigation policies, notably in the context of the so-called "California" or "Brussels effects" (Vogel, 1997[45]; Bradford, 2015[46]). Robust empirical evidence is limited. Some of the available studies have assessed the adoption of emission performance standards for passenger cars, and suggest that countries whose major export markets maintain stringent standards are more inclined to adopt similar levels of stringency themselves (Perkins and Neumayer, 2012[145]; Saikawa, 2013[146]). Yet the quantitative design of these studies makes it challenging to demonstrate direct causal links. More recently, attention is shifting to the potential of BCAs for inducing policy spillovers by inducing the adoption of carbon pricing among trading partners. Anecdotal evidence on reactions to EU CBAM indicates that it has prompted several jurisdictions, including India, China, Indonesia, Morocco, Türkiye, Ukraine, Uruguay, and Western Balkan countries, to introduce, consider implementing or reform their carbon pricing policies to keep carbon pricing revenues at home and avoid losing market share in the EU (Otto, 2025[147]; World Bank, 2024[148]; IETA, 2024[149]). Overall, the extent to which domestic policies succeed in generating policy spillovers can depend both on their design and the market size of the implementing jurisdiction (see Box 3.2).

Finally, several studies indicate that the incorporation of environmental clauses into trade and finance agreements can spread stricter mitigation policies to trading partners (Bastiaens and Postnikov, 2017[150]; Jinnah, 2011[151]; Abman, Lundberg and Ruta, 2024[152]). For instance, Brandi, Blümer, and Morin (2019[153]) find that countries entering into trade agreements which include environmental provisions are significantly more likely to adopt new domestic environmental laws, particularly in developing economies–suggesting that such clauses can be a catalyst for regulatory reform. New approaches with a focus on incorporating environmental policy into trade agreements are also emerging, such as the Agreement on Climate Change, Trade, and Sustainability signed in November 2024 between Costa Rica, Iceland, New Zealand, and Switzerland (Tipping et al., 2024[154]).

Box 3.2. The role of a jurisdiction’s economic size on spillovers

A country’s economic size may affect the magnitude of the international spillovers a domestic mitigation policy creates. In terms of policy spillovers, the “California” or “Brussels effects" suggests that large economies can leverage their market power to unilaterally set implicit global standards, through actions such as product standards, trade agreements, or unilateral measures. For smaller economies, heavy trade exposure to these markets creates strong incentives to converge with the regulatory practices of the larger jurisdiction, whether by adopting similar laws or through practice. Conversely, smaller economies acting alone may lack the leverage to impose their standards internationally but could still foster to policy diffusion through peer-learning and peer-pressure.

Domestic market size can also influence the strength of technology and economic spillovers. For example, the implementation of demand-pull and technology-push instruments in large markets may create stronger spillover effects than the implementation of the same instrument in smaller markets since they provide a larger addressable market.. Moreover, given that large economies account for a larger share of global demand and production, their policies can shift prices for fossil fuels, energy-intensive goods, or low-carbon technologies. These price movements propagate across borders, influencing production and consumption decisions elsewhere, even in jurisdictions that did not adopt similar policies. By contrast, price effects originating from smaller markets that act unilaterally are less likely to be transmitted globally.

3.3. Evidence on outcomes

3.3.1. Evidence on emission outcomes

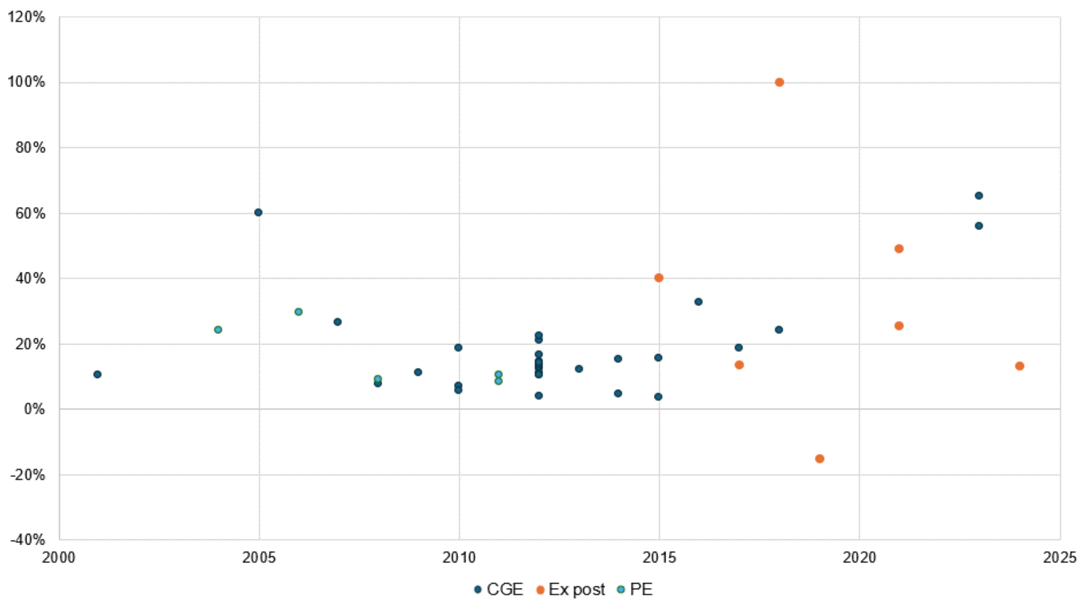
The literature on the impact of spillovers on emission outcomes has to date largely focused on carbon leakage risks. In this area, results from ex-ante and ex-post studies have recently started to convergence. Studies focusing on technology and policy spillovers have concentrated on establishing their existence and magnitude rather than measuring their effects on emission outcomes.

Results from ex-ante studies on carbon leakage were in general larger than those from ex-post studies. More specifically, quantification of the carbon leakage rate from ex-ante analyses range from 5 to 30% while ex-post studies conducted in the 2000s and 2010s pointed to little to no leakage effects (Branger and Quirion, 2014[155]; Carbone and Rivers, 2017[156]; Cameron and Baudry, 2023[31]). Figure 3 provides an overview of carbon leakage estimates from selected studies

Several factors can explain the discrepancy between results from ex-ante models and from earlier ex-post empirical studies . Most ex-ante studies provide forward-looking projections based on changes in mitigation policies (such as carbon prices or complete phase-out of fossil fuel subsidies) that are large compared to the actual changes in policies recorded so far. This is because ex-ante studies attempt to reflect the policy action needed to meet long-term climate objectives. Ex-ante models may also miss relevant features of the economy due to high levels of aggregation, inaccurate representations of preferences, technologies, market structure and institutions, or lack of sector-specific details.[2] Ex-post studies may underreport carbon leakage effects by incompletely capturing the international energy prices and technology channels as well as downstream and long-term effects. In addition, empirical studies often fail to consider safeguards mechanisms (e.g. free allowances in ETSs) that government offer to protect firms in sectors most at risk of carbon leakage (Grubb et al., 2022[141]; De Vivo and Marin, 2018[157]; OECD, 2020[48]). Moreover, the reliance of ex-post studies on historical data means that most of the available empirical evidence (except for the most recent studies) does not capture the recent increase in the carbon price differentials across jurisdictions. Thus, the modest or zero carbon leakage effects identified in earlier empirical studies may not be a reliable guide of future developments, especially if large and asymmetric changes in mitigation policies across countries persist or continue to widen.

Figure 3. Estimates of carbon leakage rates in existing literature

Leakage rate in percentage



Note: CGE for Computable General Equilibrium ex-ante models. PE for Partial Equilibrium ex-ante models. The dots represent average estimates of carbon leakage rates reported in studies.
Source: OECD (2025, forthcoming)

Ex-post estimates of carbon leakage through the trade channel have mostly relied on international trade data. Aichele and Felbermayr (2015[158]), for instance, investigate the carbon content of trade in the context of the Kyoto Protocol. Their analysis finds that countries with binding commitments under the protocol experienced an increase in the carbon embedded in imports by 8% compared with non-committed

[2] On the one hand, effects could be overestimated due to a lack of differentiation of responses in foreign countries and sectors. On the other hand, the effects can be underestimated of the cost change in a specific subsector gets muted through an aggregation in a larger sector that is on balance less exposed.

countries Moreover, the emission intensity of their imports rose by about 3%, indicating a shift toward more carbon-intensive imports compared with non-committed countries. Naegele and Zaklan (2019[159]) employ a gravity model to analyse the carbon content of trade at the firm level to and from the EU and find that the EU ETS did not cause carbon leakage. In a different approach focussing on economy-wide emissions, Eskander and Fankhauser (2023[160]) study the impact of climate policy on carbon imports and exports across 98 countries and find that countries that implement climate laws reduce their consumption-based emissions with a three-year lag, implying that these countries reduce the carbon content embodied in their imports as a result of their climate laws. Notably, they show no evidence that domestic climate policy led to international carbon leakage and in fact suggest that the leakage rate might be negative.

Carbon leakage has also been empirically analysed through the use of firm and facility-level data. Dechezleprêtre, Dussaux and Vona (2020[161]) take this approach in the context of French manufacturing firms and identify no effect of more stringent climate policy on firms' total emissions. Instead, firms that offshored their emissions abroad exhibited better emission efficiency in those foreign locations. Dechezleprêtre et al. (2022[162]) update and extend this study to an international sample of firms and similarly find no evidence of carbon leakage. Also using firm-level data, Colmer et al. (2024[163]) examine the outsourcing behaviour of firms under the EU ETS and find that firms did not increase outsourcing as a result of the policy and they successfully reduced their emissions. This indicates the EU ETS effectively encouraged firms to adopt more decarbonised practices rather than shifting production overseas. Using a novel dataset that combines more than 1 500 multinational firms' subsidiary locations with spatial emission data and variations in firms' exposure to carbon prices across European countries from 2010 to 2019, Känzig, Marenz and Olbert (2024[26]) study carbon leakage effects to developing countries. They show that emissions and economic activities at African subsidiaries of more exposed multinational firms rise relative to subsidiaries of less exposed firms, identifying leakage effects to least regulated jurisdictions, which are mostly located in Sub-Saharan Africa.

Some recent ex-post studies have found larger carbon leakage rates than earlier studies and in the middle of the range of ex-ante estimates. For example, Koch and Basse Mama (2019[164]) and Borghesi, Franco and Marin (2019[165]) identified an increase in the investment of German and Italian firms in less constrained jurisdictions following the implementation of more stringent climate policies in the EU. Kuusi et al. (2020[166]) is one of the first studies to empirically identify significant carbon leakage, at a rate of 20% at EU level over the 2005-15 period. Accounting for the international energy prices channel by exploiting sector-country-specific changes in energy prices that occurred between 2005 and 2015, Misch and Wingender (2021[167]) estimated carbon leakage rates across jurisdictions between 7 and 46%, particularly sizeable in small open economies, with an average rate of 25%. A study from the European Central Bank (ECB) also identified a significant carbon leakage rate of 23% at EU level between 2005 and 2016 (Böning, Di Nino and Folger, 2023[168]). More recently, Teusch et al. (2024[169]) found an overall leakage rate of 13% for steel and cement products using data from 2015 to 2021, a period marked by rising divergence in carbon prices across jurisdictions.

Beyond carbon leakage, limited data on government support for low-carbon industries hampers direct assessment of its impact on emissions. Nonetheless, as such support typically reduces technology costs and expands recipient firms' global market share, its effects may be observed indirectly through the relationship between trade and emission reductions, discussed below.

Evidence on the impact of policy-induced innovation and learning-by-doing on emission outcomes is limited. The ex-post evaluations of the relationship between demand-pull and technology-push policies and global low-carbon technology innovation predominantly focus on innovation outcomes, often measured in patent filings (as for example in Hille, Althammer and Diederich (2020[79]), and generally do not quantify the impact on emission outcomes. This is partly due to challenges relating to attribution, data availability and isolating causal mechanisms.[3] The few studies that analyse the overall relation between low-carbon technology innovation and emissions suggest that innovation leads to emission reductions, but that this effect is most pronounced for high-income economies (Du, Li and Yan, 2019[170]; Töbelmann and Wendler, 2020[171]).

Recent evidence indicates that technology diffusion through trade contributes to emission reductions. Using patent and trade data, Rahko and Alola (2024[172]) find technology spillovers—particularly those mediated through trade—have reduced emissions in selected European countries more than domestic innovation; a 10% increase in foreign low-carbon technology patent stocks is associated with a 1.9–2.6% reduction in emissions. Gallagher et al. (2025[117]) similarly show that Chinese exports of low-carbon technologies, drive sizable reductions, particularly in high-income countries. Moving beyond cross-country panel approaches, Liu et al. (2019[173]), find sizable emission reduction impacts of Chinese solar PV exports, through the displacement of power generation from fossil fuels, but they rely on simplifying assumptions about power-sector intensity and solar PV output. Addressing these limitations with micro data and integrated modelling, Wang et al. (2021[174]) project that halving the 2017-level global PV trade barriers could deliver an additional 4–12 $GtCO_2e$ reduction by 2060, whereas new barriers could reduce mitigation by up to 4 $GtCO_2e$ relative to business as usual.

The impact of FDI on emission outcomes is well studied —often in the context of the pollution haven hypothesis—but evidence on the impact of knowledge exchanges on low-carbon technologies is limited.[4] A meta-analysis of 65 studies reports that increases in FDI significantly lower emissions, especially in developed economies (Demena and Afesorgbor, 2020[175]). Other studies associate FDI with higher shares of renewable energy use (Hernández Soto, 2024[176]), and energy efficiency improvements (Erdem, 2012[177]).

Evidence shows that policy spillovers help spread mitigation policies across countries, but quantitative links to actual GHG reductions remain scarce. Most studies examine diffusion to predict adoption rather than measure emission outcomes, and ex post attribution is hampered by data gaps and causality issues. Notable exceptions include a study by IMF staff that merges carbon pricing diffusion patterns with assumed annual abatement rates and compares it to scenarios without diffusion to estimate the impact of policy diffusion (Linsenmeier, Mohommad and Schwerhoff, 2022[138]). It finds that policy diffusion has contributed to significantly to global emission reductions. Another study found that as the EU lowered emissions over the past decades, neighbouring countries with strong economic and financial ties to the EU reduced their own emissions more than other countries (Cevik et al., 2023[178]).

3.3.2. Evidence on economic outcomes

The literature has investigated the effects of international spillovers on economic outcomes such as GDP, sectoral outputs, and trade and others (OECD et al., 2024[1]). These effects occur primarily through changes in fossil fuel prices and international trade competitiveness. While the overall economic impacts can be modest at the aggregate level, they are often unevenly distributed across countries and sectors. Studies show that the magnitude and direction of economic outcomes depends heavily on the transmission channels and contextual factors (Böhringer, Peterson and Weyant, 2022[179]).

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[3] For example, as Haščič and Migotto (2015[360]) highlight, while patent data can be useful and widely available proxy for innovation, it does not provide information on the quality of innovation or their subsequent commercialisation and diffusion.

[4] According to the pollution haven hypothesis, asymmetry in stringency of climate policies across countries may encourage pollution-intensive industries tend to relocate or expand production in jurisdictions with the weakest regulations to reduce compliance costs, effectively turning those jurisdictions into "pollution havens" (Koźluk and Timiliotis, 2016[322])

Shifts in fossil fuel prices are expected to lead to large economic impacts in open countries. Uncertainty around climate policy, fossil fuel investment, and technology development makes future demand and price projections challenging (Puyo et al., 2024[51]), but overall fossil fuel prices are expected to decrease significantly under net-zero scenarios (IEA, 2021[180]). Ex-post evidence on sustained declines in extractive industries points towards persistent negative effects on GDP, trade balances, and broader economic performance in fossil fuel-producing economies (Bems et al., 2023[181]). Emerging economies with high production costs and reliance on fossil fuel exports and limited diversification options would face the most adverse impacts, while low-cost producers could capture of additional market share (Puyo et al., 2024[51]). Oil producers could see more significant revenue drops than gas producers (IMF, 2023[182]; Jensen, 2023[183]). In contrast, fossil fuel importers may see gains (Baffes et al., 2015[184]).

The trade and competitiveness channels are expected to mostly impact EITE and low-carbon technology sectors. Ex-ante analyses suggest, greater divergence in stringency across countries tends to increase pressures on competitiveness—and, accordingly, expected welfare losses (Lanzi, Chateau and Dellink, 2012[185]). Yet, evidence from the EU ETS suggests it has had no significant impact on profits or employment of regulated firms, including in EITE sectors deemed at risk of carbon leakage (Dechezleprêtre, Nachtigall and Venmans, 2023[186]; Verde, 2020[187]).

While markets for low-carbon technologies are projected to expand significantly, the ability to benefit from participating in related value chains differs across countries. According to the IEA (2024[188]), clean energy industries contributed to 10% of global GDP growth in 2023. Under the current mitigation policy setting, trade in low-carbon technologies is projected to reach USD 575 billion by 2035 (IEA, 2024[113]). Nevertheless, manufacturing-related benefits have thus far primarily accrued to firms in a limited number of countries. China currently accounts for approximately 70% of the global value of key low-carbon technology manufacturing—and also the largest share of associated jobs—while emerging economies in Latin America, Africa, and Southeast Asia together generate less than 5% (IEA, 2024[113]). Manufacturers in China benefit among other things from larger economies of scale, highly integrated supply chains, and substantial government support (IEA, 2024[113]; IEA, 2022[189]; OECD, 2023[29]). Economic spillovers caused by large-scale industrial policies have likely influenced the current distribution of manufacturing; recent developments in trade related measures in some economies may further shape this distribution of manufacturing activity in the future (OECD, 2025[134]). However, due to data limitations and the lack of robust evidence on the effects of government support, their impact on economic outcomes remains difficult to quantify.

Technology spillovers can deliver broad economic gains by accelerating the deployment and innovation of low-carbon technologies, though their manufacturing remains concentrated in few countries. Wider access to affordable low-carbon technologies drives greater investment in energy and industrial capital (Hasna et al., 2025[130]; OECD/UNDP, 2025[57]), directly supporting GDP and jobs in construction, installation, and operations of for example renewables. Global analysis suggests sizable employment effects. Irena estimates 11.6 million additional energy-sector jobs under accelerated renewables deployment (Gielen et al., 2019[190]), the IEA (2021[180]) and foresees 14 million new clean energy jobs in its Net Zero Emissions by 2050 Scenario. ILO (2018[191]) projects a net increase of 18 million jobs when meeting the Paris Agreement goals.

Evidence also sugests that, over the longer run, greater deployment of low-carbon technology can raise productivity. For G7 countries, imports of low-carbon technology are associated with higher total factor productivity and GDP per capita (Herzer, 2025[192]), while OECD/UNDP (2025[57]) projects that accelerated electrification and uptake of efficient technologies would lift GDP by 0.17% in 2035 and 0.34% in 2040 under an Enhanced NDCs scenario. Expanded access to…….also enables countries to leverage comparative advantages—such as rare-earth endowments or abundant renewables—to participate in low-emission value chains (e.g., low-carbon steel, green hydrogen) (Pérez-Hernández, Montiel-Hernández and Salazar-Hernández, 2025[58]; Venkataraman et al., 2022[193]). These developments may shift EITE supply chains toward regions with plentiful, low-cost clean energy (Bataille, Nilsson and Jotzo, 2021[194]).

With regard to policy spillovers, numerous ex-ante studies examine how countries can best react to policy action abroad or its absence. This includes also the above-mentioned literature on carbon leakage impacts. One strand of the literature looks at optimal climate policy from a coalition formation perspective to identify incentives for countries to change their mitigation efforts in light of actions by others (see e.g. (Lessmann et al., 2015[195]; Barrett, 1994[196]))Several studies for example assess the economic exposure to a BCA or determine what type of response—such as adopting or raising carbon prices domestically— would be welfare maximising (Clausing et al., 2025[197]; Dechezleprêtre et al., 2025[198]; Eicke et al., 2021[55]). Impacts and optimal responses vary across countries depending on trade exposure, production costs and carbon intensity of production.

Other studies focus on the positive economic spillovers resulting from better alignment of policies across countries. Li and Duan (2021[199]) show that a scenario with full linkage between China's national ETS and the EU ETS could result in significant welfare gains for both regions. These gains arise from trading of emission permits among the two jurisdictions, which allows for the reallocation of abatement efforts to regions with lower marginal abatement costs leading to lower total compliance costs (i.e. equi-marginal cost principle). Winkler et al. (2021[200]) found that while ETS linking may be welfare-enhancing for both the EU and China, benefits are unequally distributed, due to differences in reduction targets and market structures.

4. Policy settings impacting international spillovers

Main messages

This section discusses how policy settings can help enhance the effectiveness of global emission mitigation efforts and limit negative economic impacts.

Its main messages are:

- **Countries can leverage domestic mitigation policies or policies relating to foreign emissions ("internationally oriented measures") to attenuate or amplify spillovers.** Internationally oriented measures include, e.g., unilateral policies pertaining to foreign emissions and policies, and international co-operation.
- **Policy instrument design features can be geared towards spillovers in various ways.** Examples include free allowances under emission trading schemes (ETSs), preferential rates within carbon pricing schemes, and targeting in climate-related corporate income tax incentives. These features can impact emission spillovers, e.g. by reducing the cost of emissions for eligible firms, or technology spillovers, e.g. by supporting a broad range of technologies.
- **Combining instruments in policy packages can also influence spillovers.** For example, a carbon intensity-based regulation for industrial firms can be combined with direct subsidies for emerging technologies, to make the whole package more budget neutral for firms. More generally, policy instruments that increase the cost of emissions may be combined with cost-decreasing measures for negatively impacted sectors. By reducing compliance costs for firms, such policy packages may help address economic spillovers. They may also enhance technology spillovers by increasing the competitiveness of low carbon production.
- **Domestic and unilateral policies relating to foreign emissions can, e.g., seek to ensure equivalent costs of emissions or equivalent emission outcomes for imported products.** They can apply to both domestic and foreign emissions, or to foreign emissions only. Examples include border carbon adjustments (BCAs), mandatory product standards, or excise taxes on domestic consumption.
- **Internationally oriented measures can also take the form of international co-operation solutions.** International co-operation includes initiatives such as voluntary international sectoral agreements (e.g. the International Maritime Organization Net-zero Framework, the Carbon Offsetting and Reduction Scheme for International Aviation, and the Global Methane Pledge); international policy approaches, such as international mandatory product standards on emissions intensity or the linking of carbon markets; and organisational arrangements, including

international licensing agreements, joint ventures, research collaborations, and training programmes.

- **Spillover effects depend on the specificities of design**. For example, the allocation of free allowances based on historical emissions (i.e. grandfathering) may be less likely to generate technology spillovers than benchmark-based allocation linked to best performance. The type of product-level carbon intensity metric (firm-specific or country-specific) used to design BCAs is another example. This underscores the need to examine detailed design options that might ultimately affect spillovers.

4.1. Policy settings can influence international spillovers

Countries have a range of options to encourage positive emission outcomes and limit negative economic outcomes. Countries may rely on their domestic mitigation policies to leverage some of their design features or use certain combinations of instruments (policy packages). Even though the impact of these design features and policy instruments on spillovers may not necessarily be intended (i.e. they may have been introduced for different policy objectives), the section outlines their relevance in the context of emission and economic outcomes. Countries may also rely on unilateral measures that pertain to foreign emissions or international cooperation ("internationally oriented measures"). More specifically, the following policy settings are discussed in this Section:

- Within domestic mitigation policies:
  - **Policy instrument design features can impact spillovers in various ways.** Examples of such features include free allowances or other compliance options that ease compliance costs for businesses (e.g. the use of carbon credits for compliance under ETSs or carbon taxes), preferential tax rates within carbon pricing, or targeting in climate-related corporate income tax (CIT) incentives.[5] These features can impact emission spillovers (e.g. by reducing the cost of emissions for eligible firms) or technology spillovers (e.g. by supporting a broad range of technologies).
  - **Combining instruments in policy packages can also influence spillovers.** Examples of such policy packages include the combination of regulations based on environmental performance indicators (such as emission intensity or resource efficiency) with direct subsidies that would make the whole policy package more budget neutral for firms. More generally, policies increasing the cost of emissions can be combined with cost decreasing measures for selected firms. By reducing compliance costs for firms, such policy packages may help address economic spillovers. They may also enhance technology spillovers by increasing the competitiveness of low carbon production.
- Within internationally oriented measures:
  - **Unilateral policies that pertain to foreign emissions can aim to ensure equivalent cost of emissions or equivalent emission outcomes for imported products.** Examples include border carbon adjustments (BCAs), mandatory product standards, or excise taxes on domestic consumption covering both domestic and imported goods. The specificities of their design (e.g. the base chosen) can significantly influence how these can impact the different spillover types (technology, economic, policy).

[5] The term compliance costs is used here to mean the sum of costs of abating emissions and costs of residual emissions (as in e.g. Naegele and Zaklan (2019[387])) and does not cover costs that a company uses up to adhere to government regulations.

- **Internationally oriented measures can also take the form of international co-operation solutions.** These include initiatives such as voluntary international sectoral agreements; common policy approaches, such as international mandatory product standards on emissions intensity or the linking of carbon markets; and organisational arrangements, including international licensing agreements, joint ventures, research collaborations, and training programmes.

Spillover effects depend on the specificities of design. For example, the allocation of free allowances based on historical emissions (grandfathering) is less likely to generate technology spillovers than benchmark-based allocation linked to best performance. This underscores the need to examine policy design to understand how a measure could ultimately affect spillovers. The granularity of carbon intensity data used for policy design may also affect the type of spillovers generated, and this is relevant across the policies discussed in the following sections.

One common consideration for policy design is the utility of granular carbon intensity metrics for defining sectors and firms at risk of carbon leakage. Identifying vulnerable sectors is relevant across a range of policy instruments, including the allocation of free allowances, preferential carbon tax rates, and the eligibility criteria for subsidies or tax incentives. The definition of such sectors is closely linked to the availability and granularity of carbon intensity data. The more aggregated the carbon intensity metrics, the less heterogeneity they capture, an important limitation when assessing leakage risk (Cameron, 2025[201]). Using overly aggregated metrics may overstate leakage risks (Fischer and Fox, 2018[202]). In turn, overestimating carbon leakage risk when determining free allowance allocations or preferential carbon tax rates may weaken emission reduction incentives for affected firms and, consequently, limit technology spillovers.

This section provides an overview of policy settings – as well as some underlying key design specificity considerations – that impact international spillovers. The analysis focuses on selected issues to guide considerations on how to enhance the effectiveness of global emissions reduction efforts while promoting economic growth and competitiveness.

4.2. Domestic mitigation policies: policy instrument features and policy packages

4.2.1. Policy instrument features

Within ETSs, the allocation of free allowances is a widely used feature to address the concern of carbon leakage. By making the instrument budget neutral for eligible firms, free allowances limit the rise in costs among targeted firms. As such, they may help address concerns linked to the economic spillovers channel. The specificities of design of free allowances allocation can vary along several dimensions, including the calculation method (benchmark setting, dependence on historical emissions and production (OECD, 2025[203]), targeted sectors, or specific conditions for entering firms (OECD/Climate Club, 2024[2]).

The modalities of free allowance allocation influence decarbonisation incentives and investment decisions and, therefore, can also impact technology spillovers. In general, free allowances tend to weaken the overall carbon price signal and limit changes in demand for low-carbon technologies (OECD, 2020[48]; Zaklan, 2023[204]). Their specific design is crucial for their effectiveness. For instance, free allowances allocated on the basis of historical emissions (grandfathering) may reduce incentives for firms to decarbonise and therefore may not enhance positive technology spillovers. In contrast, benchmark-based allocation linked to best performance encourage the adoption of low-carbon technologies at the margin and can create stronger incentives for innovation and diffusion of low-carbon practices (Dechezleprêtre, Nachtigall and Venmans, 2018[205]).

The way benchmarks are set in free allowance allocation can also impact spillovers. The granularity of benchmarks can influence technology diffusion. The more granular the carbon intensity metric used to set the benchmark, the narrower the set of abatement options it promotes, thereby limiting the scope of technology spillovers. In contrast, uniform or technology neutral benchmarks can increase abatement options and thus enhance technology spillovers.[6] The scope of emissions can also influence economic and technology spillovers. Most benchmarks typically include only direct emissions (i.e. Scope 1 or on-site emissions), excluding indirect emissions (i.e. Scope 2 – i.e. purchased electricity and heat – and 3 emissions – i.e. in other parts of the value chain) from the scope of product benchmarks. This can lead to incomplete coverage of firms' costs, and limit the safeguard of their competitiveness. It might also lead firms to focus primarily on reducing direct emissions, rather than seeking to minimise overall emissions along the supply chain (Zipperer, Sato and Neuhoff, 2017[206]). This, in turn, affects where in the supply chain technology spillovers are most likely to occur.

The different compliance options offered in ETSs – in particular options for the use of carbon credits – also can affect emission and economic outcomes through international spillovers. ETSs offer a range of compliance options beyond trading and free allowances, with the use of carbon credits (also referred to as "offsets") being relatively widespread (OECD, forthcoming[207]). This mechanism allows covered entities to meet ETS compliance obligations by purchasing credits generated from emission reduction or greenhouse gas (GHG) removal projects outside the ETS scope, thereby diversifying compliance sources. The use of carbon credits for compliance in ETSs can stimulate mitigation incentives and technology spillovers in sectors that are outside the scope of the ETS or pricing schemes —such as agriculture, forestry and other land use (AFOLU). This may be especially useful in countries where these sectors account for a large share of domestic emissions (Wetterberg, Lanzi and Gómez, 2025[208]). Other compliance options include the possibility to bank or borrow credits. By increasing temporal, spatial and sectoral flexibility, banking, borrowing and carbon credit use can provide firms covered by the ETS with more flexibility to comply with this instrument.

Exemptions, reduced rates or rebates for energy use for specific sectors or products within carbon tax design are another policy feature relevant to international spillovers (OECD/Climate Club, 2024[2]; OECD, 2023[209]). . Preferential treatments can weaken decarbonisation incentives and risk reducing innovation and adoption incentives, potentially negatively impacting low-carbon technology spillovers across countries. However, the extent to which preferential treatment will impact technology spillovers ultimately depends on its specific design, e.g. on the scope of eligibility criteria and the reduction rate applied.

Corporate income tax (CIT) incentives that support clean investment can include policy features with implications for international spillovers and outcomes. When introducing CIT incentives to promote clean investment, governments typically have a range of designs features on which to make choices (Dressler and Warwick, 2025[9]). These choices shape potential international spillover effects.

The degree of targeting in CIT incentives influences technology spillovers. Narrowly targeted CIT incentives that support the acquisition of specific clean assets differ from more broadly targeted incentives that apply to entire sectors, such as renewable power generation, or to any reduction in energy use. Narrow and specific targeting may limit incentives to innovate and lessen technology spillovers by promoting only a restricted set of abatement options. This is particularly the case when CIT incentives rely on technology lists that are irregularly updated, increasing the risk of technology lock-in. Conversely, if regularly updated (e.g. in the Netherlands, the corporate tax allowances EIA and MIA rely on regularly updated lists of eligible technologies to provide support (Anderson et al., 2021[210])), such lists can enhance investment

[6] Nevertheless, differentiated (granular) benchmarks may be preferred in certain cases, for example when emission boundaries are less clear, where variations in associated scope 1 and scope 2 emissions highly vary by process, or where product characteristics vary in their quality and applicability (Kuneman et al., 2022[386]).

additionality by focusing on emerging technologies and limit revenue costs compared to broad-based incentives (Dressler and Warwick, 2025[9]). In doing so, they may foster spillovers related to the diffusion of low-carbon technologies.

The impact of CIT incentives on spillovers can also depend on the scale of fiscal incentives and local content requirements. By supporting the production and use of emerging technologies, fiscal incentives can play a role in stimulating innovation and enhancing technology spillovers. However, beyond a certain level of expenditure, these may also generate crowding-out effects, thereby limiting additional gains in technology diffusion (Fan and Shi, 2025[211]). Furthermore, local content requirements embedded in CIT incentives can influence the nature and extent of economic spillovers and outcomes.

4.2.2. Policy packages

Differences in policy objectives, economic contexts, and market failures lead to differences in mitigation policy approaches across countries. Emission reduction targets and broader policy priorities differ across countries. Countries also face different economic and social circumstances, including the sectoral composition of the economy, administrative capacity, fiscal constraints, level of development, and natural resource endowment. The presence and extent of market failures in the product, labour and financial markets further shape the choice and mix of mitigation policies.

The combination of multiple mitigation policy instruments (mitigation policy packages) can affect the effectiveness of emission mitigation efforts and the capacity to limit negative domestic economic impacts. For instance, subsidies or tax incentives for low-carbon technologies can help firms cope with the transition. In the short term, by e.g. reducing the costs of adopting low-carbon technologies, subsidies or tax incentives (demand-side policies in this case) can ease costs from carbon pricing or regulations. In the long term, by increasing the availability of low-carbon technologies and production pathways, supply-side policies such as e.g. R&D subsidies can increase the availability of low-carbon alternatives, hence substitution possibilities for firms – thus facilitating decarbonisation. The combination of multiple mitigation policy instruments can thus affect economic spillovers. Moreover, the combination of cost-reducing policies with stringent regulations or carbon pricing can also contribute to enhance the effect described by the Porter hypothesis (see Section 2.2), thereby enhancing technology spillovers. Such measures can be targeted to the same sectors (e.g. pricing and technology support in industry) or to different interconnected sectors (e.g. pricing in industry and renewable energy support in electricity).

Several jurisdictions that have carbon pricing in place are also deploying subsidies for emerging technologies. These include the EU Innovation Fund (European Commission, 2025[212]), Japan's Green Transformation Plan (Ministry of Economy, Trade and Industry of Japan, 2024[213]), Korea's New Deal (Ministry of Economy and Finance of Korea, 2021[214]), and the France's 2030 Investment Plan (Government of France, 2021[215]).

4.3. Internationally oriented measures: unilateral policies and international co-operation solutions

4.3.1. Unilateral policies

Unilateral policies pertaining to foreign emissions can be aimed at ensuring equivalent costs of emissions or equivalent emission outcomes for imported products. Examples of such policies include BCAs, import tariffs designed to equalise domestic and foreign carbon costs, excise taxes on domestic consumption, and mandatory product standards. These instruments may address carbon leakage risks and impact economic outcomes; and depending on the specificities of design, they may operate through all three spillover channels (economic, technology and policy). Given the strong link between climate and trade considerations in these policies, one important aspect of these policies is their compatibility with World Trade Organisation (WTO) rules (OECD, 2020[48]).

BCAs may be defined as measures that seek to address carbon leakage by levelling carbon costs of (a selection of) traded products. The most frequently discussed BCAs consist of levies on the carbon content of imported products, that level carbon costs with those of the domestic regime. BCAs include two components: the levy and the base, the design of which can impact the different spillover channels. The levy is generally determined with reference to a domestic benchmark and could account for different types of policies. The base is generally the carbon intensity of production (residual emissions), which could be measured in different ways (with different boundaries or different granularity) (see discussion in Box 4.1). Other specificities of design which may matter include the scope of carbon emissions, geographic and product coverage as well as the use of revenues (OECD, 2020[48]).

BCAs relate also to economic spillovers as they reduce differentials in production costs due to carbon pricing. As with other instruments, policy design plays a critical role. The type of policies accounted for in the levy and the accompanying base may reflect cost differentials to different degrees, but this may come with trade-offs (Box 4.1). For example, in terms of the base, whether the BCA applies only to imports or also to exports can affect economic spillovers. Applied solely to imports, BCAs may reduce the risk of carbon leakage by subjecting imports to a comparable carbon price. Addressing competitiveness concerns related to domestic exports is challenging, however, because of potential incompatibility of export rebates with WTO rules (OECD, 2020[48]). Ex-ante modelling exercises suggest that BCAs can effectively tackle carbon leakage (Nachtigall et al., 2021[216]; Mörsdorf, 2022[217]; Dechezleprêtre et al., 2025[198]; Branger and Quirion, 2014[155]) in a way that is more effective than free allowances (OECD, 2020[48]).

BCAs may also influence technology spillovers by creating incentives for producers abroad to decarbonise. Installation-specific product-level carbon intensity data could strengthen incentives for foreign firms to reduce emissions. At the same time, this may create the risk of resource shuffling, whereby producers allocate their least emission-intensive products to BCA jurisdictions while directing more emission-intensive products to other markets (Böhringer et al., 2022[132]). This might then prevent the widespread adoption of clean technology. Relying on regularly updated product-level default values from the exporting country could promote more widespread technology spillovers through country-level responses–but would come with potential trade-offs outlined in Box 4.1, IISD (2025[218]).

BCAs may also enhance policy spillovers by encouraging foreign countries to reduce exposure to the border levy by reducing embedded emissions and adopting policies that reduce levies per unit of embedded emissions. By adopting as a base the carbon intensity of production, these policies implicitly recognise countries' mitigation efforts. Moreover, by explicitly recognising in the levy policies that price residual emissions (e.g. carbon taxes, emissions trading systems, carbon credits or fuel excise taxes) in a foreign country, BCAs may encourage the adoption of these policies abroad, especially since revenues will accrue to the foreign government rather than the country imposing the BCA. Expanding the scope to include abatement costs from non-pricing policies could support the diffusion of these policies in addition to carbon taxes. Methodological and conceptual challenges in the computation of the carbon price equivalent of non-pricing policies could make such an approach difficult to operationalise (see Box 4.1).

Another example of unilateral policies is an import tariff that applies a uniform, product-specific, and non-discriminatory charge reflecting the average carbon cost faced domestically. While not directly linked to the carbon content of imported goods, such tariffs may achieve the objective of offsetting the cost disadvantage experienced by domestic producers as a result of carbon pricing instruments (Campolmi et al., 2023[219]). The aim of such a measure is limited to managing economic spillovers and reducing carbon leakage risks but it does not provide incentives for foreign producers to decarbonise. Policy spillovers may be weak or even negative, as such charges do not acknowledge foreign mitigation policies, and risk being perceived as protectionist trade measures.

Excise taxes on the carbon content of domestically consumed goods—applied equally to locally produced and imported products—offer a consumption-based alternative to BCAs. Their primary aim is to ensure that domestic and foreign products face an equivalent carbon cost in the domestic market. The rates of excise taxes could generally be based on the average carbon content of the goods (or on product benchmarks). With sufficiently granular product categories and the availability of carbon intensity metrics at this level of detail, low-carbon goods would become cheaper than their high-carbon counterparts.

Excise taxes can mitigate economic spillovers for less carbon-intensive firms. Excise taxes can affect the competitiveness of domestic and foreign firms to the extent that they reflect differences in carbon intensity: more carbon-intensive domestic and foreign producers lose competitiveness, while less carbon-intensive producers gain.

Excise taxes may also generate technology and policy spillovers. The extent of these impacts depends on the granularity of product categories used for carbon intensity computation. When excise tax rates are based on the average carbon intensity of goods, they are amenable to a wide product coverage and provide flexibility for rate adjustments over time, but may not create strong incentives to switch to low-carbon production processes for a given good (OECD, 2020[48]). Relying on the more granular product category averages (that e.g. account for the production process) can strengthen incentives to decarbonise at home and abroad (OECD, 2020[48]; Neuhoff et al., 2016[220]; OECD, 2024[221]). Further, excise taxes also generate revenues for the domestic government, which can be used for investments in low-carbon technology innovation or adoption – or for other public policy goals. Finally, similarly to BCAs, policy spillovers may also be enhanced, since abatement efforts are implicitly taken into account by applying to the carbon content of goods – these spillovers would be enhanced if such excise taxes are adopted widely or in large markets.

Mandatory product standards based on environmental indicators, such as emission intensity or resource efficiency, applied to both domestic and imported products (van Asselt, 2017[222]; OECD, 2024[221]) **also affect spillovers**. Such standards can stimulate the development of markets for low-carbon goods (and thus enhance technology spillovers) and indirectly address negative domestic economic spillovers by requiring all producers to meet the same carbon content requirements. At the same time, they may entail significant administrative costs, including the need for comparable methodologies, verification, and certification (OECD, 2015[223]; OECD, 2024[224]). Setting effective ceilings is also challenging and can have adverse efficiency impacts to reduce emissions, as standards tend to promote compliance-oriented rather than open-ended innovation. Such issues can be mitigated by setting benchmarks on a declining trajectory. To enhance their effectiveness, fairness and feasibility, mandatory product standards might include international co-operation on standards, addressing the compliance challenges for small and medium-sized enterprises (SMEs) and developing countries, and compliance with bilateral, plurilateral and multilateral agreements, including WTO rules. In terms of policy spillovers, product standards do not formally recognise or explicitly reward foreign climate policy action, though they may indirectly encourage other jurisdictions to adopt similar requirements or to adopt mitigation policies to comply with the standards.

Box 4.1. The case of policy recognition within BCAs

BCAs can be designed in various ways, relating to the base, including the boundaries accounted for and the level of granularity of base (e.g. installation, firm or country specific) and the levy, that involve trade-offs:

- Boundaries relate to the scope (e.g. Scope 1, Scope 2, Scope 3) and sources of emissions (e.g. energy-related emissions, industrial process emissions) covered in the base. The broader the boundaries, the more scope there is for addressing all three spillover channels, but this comes with more complexity (OECD, 2024[224]; OECD, 2025[203]).
- Level of granularity of the base measure: relying on installation-specific data can allow better levelling of production costs faced by domestic producers and foreign producers. This may also provide incentives for foreign installations to reduce emissions, by e.g., technology adoption, thus enhancing the technology spillovers channel. At the same time, the risk of resource shuffling can then reduce policy spillovers. Relying on country-level averages could provide more incentives for country-level mitigation efforts, i.e. enhance policy spillovers, and could provide broader incentives for technology adoption. However, the concerned firms' costs would be less levelled, thus affecting the extent to which economic spillovers would be addressed.
- Extent of policy recognition in the setting of the levy: the levy may not account for the mitigation policies used in foreign countries, or may account for the policies which apply to the base of residual emissions – i.e. pricing policies or for a broader set of policies, by considering that at the margin, they also apply to residual emissions. However, even if the levy does not explicitly recognise policies, these may still be implicitly recognised through the base of the BCA – i.e. the carbon intensity of production.

A central question is if and how to account for foreign mitigation policies. While BCAs are typically defined with a base equal to GHG emissions embodied in imported products and a levy that credits explicit carbon prices paid in the exporting country (Case 2 below) (see for instance IISD (2025[218])), a broader conception could also encompass other design options that are elaborated below (Cases 1 and 3 below). Considering these broader design choices impacts the way BCAs address the three spillover channels. For economic spillovers, the intensity of the levy matters, and relatedly the extent to which mitigation policies are explicitly accounted for can impact the extent to which production costs are levelled. For policy spillovers and for technology spillovers, both the base choice and the explicit consideration of certain policies can matter.

1) Case where the levy does not depend on foreign mitigation policies

Under this approach, BCAs could be applied based on the carbon intensity of imported products or the differences in carbon intensities between domestic and imported products. The levy would be independent of any foreign mitigation policy (no deduction) and apply to verified emissions declarations from importers. Such BCAs would then solely focus on emissions outcomes rather than the policy mix underlying them. They may thus be interpreted as preserving neutrality and letting countries use their preferred instruments. The levy could, for instance, be based on estimated elasticities of domestic import demand and foreign export supply to increases in domestic carbon prices (Campolmi et al., 2023[219]).

2) Case where the levy depends on pricing policies

BCAs can account for policies that apply to residual emissions – i.e., pricing policies – of foreign countries. The question then arises which pricing instruments the BCA should account for – as these could be considered to include explicit carbon prices (carbon taxes, emissions trading systems), carbon credits, or potentially more broadly other forms of pricing that apply to a base proportional to GHG emissions (e.g., fuel excise taxes).

One option can be to mirror domestic policy settings: for instance, a BCA linked to a domestic carbon price would only credit foreign policies that impose an explicit price on GHG emissions. This approach allows a price deduction for the price of carbon already paid in foreign countries. Both domestic and foreign carbon prices would then consistently reflect any exemptions, rebates, or free allocations applied (Mehling et al., 2019[225]), and take into account the existence of state- (or even local-) level carbon pricing policies (Pizer and Campbell, 2021[226]). Such an approach can be transparent and hence relatively straightforward to administer. This levy design provides incentives for countries to adopt policies similar to those in the BCA jurisdiction.

Accounting for a broader set of pricing policies could further equalise costs and induce broader policy spillovers. However, extending beyond explicit carbon pricing could increase complexity and make it difficult to keep abreast of all relevant measures in all the countries covered by a BCA regime (OECD, 2020[48]).

3) Case where the levy depends on a broader set of mitigation policies

A broad approach would seek to credit all or a broad range of climate change policies that reduce GHG emissions by, for instance, estimating a carbon price equivalent across a wide range of mitigation instruments. This could get closer at levelling production costs for both domestic and foreign producers, taking into account the costs mitigation policies impose and induce broad policy spillovers.

However, the implementation of such a BCA levy could face significant challenges. First, methodological complexity arises because an extensive data collection would be required to capture the full set of mitigation policies implemented by trading partners and finding a clear delimitation of such policies to account for would be challenging (OECD, 2024[227]; OECD, 2020[48]). Second, abatement costs are not observable, creating a need for the calculation of equivalent carbon prices, which are uncertain, model dependent and sometimes lack transparency. Third, this approach could increase the potential for disputes over methodological validity and WTO compatibility, raising the risk of trade tensions.

4.3.2. International co-operation solutions

Internationally oriented measures may take the form of international co-operation mechanisms and policies. While countries aim to enhance the effectiveness of global emission mitigation efforts and limit negative economic impacts, there is a risk that increasing diversity in domestic approaches—particularly if pursued in a non-co-operative manner—could exacerbate negative spillovers. International co-operation mechanisms and policies can enhance the effectiveness of domestic mitigation efforts in reducing global emissions and the management of international spillovers.

Internationally agreed solutions through an upward alignment of mitigation action can raise the effectiveness of global mitigation efforts (OECD/Climate Club, 2024[2])**.** Such initiatives include international sectoral agreements, such as the International Maritime Organization (IMO) Net-zero Framework (OECD, 2020[48]; IMO, 2025[228]) and the Global Methane Pledge (Global Methane Pledge, 2023[229]), which foster alignment and reduce spillovers by encouraging countries to collectively set and meet higher emission reduction targets. Common policy approaches go further, ranging from implementing mandatory product standards on emissions intensity across different jurisdictions or linking carbon markets (OECD, 2020[48]; Wetterberg, Ellis and Schneider, 2024[230]) as seen between the EU and Switzerland or California and Quebec, to conceptual proposals like an international carbon price floor (Parry, 2021[231]) or climate clubs with BCAs (Nordhaus, 2015[232]). These approaches aim to ensure consistent carbon pricing and regulatory standards across jurisdictions, thereby minimising negative spillovers and delivering emission reductions.

Organisational arrangements such as licensing agreements, joint ventures, research collaborations and training programs can promote the diffusion of clean technologies. These arrangements allow for the deployment of existing and commercially proven low-carbon technologies and innovations while contributing to economic development (Pigato et al., 2020[111]). The effectiveness of such arrangements depends on the presence of robust intellectual property protection systems (Ockwell et al., 2010[233]; Falvey and Foster, 2006[234]).

Multilateral co-operation mechanisms can also facilitate the adoption and diffusion of low-carbon technologies. International technology partnerships such as the IEA Technology Collaboration Programmes (TCPs) can accelerate technological knowledge diffusion (Caiafa et al., 2023[235]). In addition, some studies have shown that market mechanisms like the Clean Development Mechanism (CDM) have achieved a degree of success in facilitating technology transfer to developing countries, both in terms of equipment and technical expertise. However, their impact on reducing emissions remains disputed (IPCC, 2023[236]) The extent of technology transfer varies significantly across projects (Seres, Haites and Murphy, 2009[237]) and the CDM alone has been considered inadequate to address host country barriers impeding the cost disadvantage of developing countries' in low-carbon technologies (Youngman et al., 2007[238]). Article 6 of the Paris Agreement–which builds on lessons from the CDM and combines government oversight with market-based co-operation–is still in the early stages of implementation and its effectiveness in supporting technology diffusion is yet to be evaluated.

Engaging globally in more integrated forms of co-operation to impact international spillovers require providing support to emerging markets and developing economies, in the form of technical and/or financial assistance. Such support is particularly relevant in areas such as transparency under the Paris Agreement and UNFCCC processes and industry decarbonisation. Several initiatives already provide such forms of support, including the Partnership on Transparency in the Paris Agreement (PATPA) and the Global Matchmaking Platform of the Climate Club (OECD/Climate Club, 2024[2]).

5. Conclusion

This report has developed a methodological framework for analysing international spillovers from climate change mitigation policies. It distinguishes between three main types—technology, economic and policy spillovers—and examines how they interact and transmit across borders to shape global emission and economic outcomes. While analytically distinct, these spillovers are closely interlinked. Failing to take these international spillovers into account risks leaving policymakers with an incomplete picture of a mitigation policy's overall effectiveness in reducing emissions and achieving wider policy objectives.

The review of evidence on international spillovers reveals a growing but fragmented body of literature. Negative economic spillovers in the form of carbon leakage have been studied extensively, though estimates vary across studies. In contrast, evidence of other economic spillovers, such as those resulting from government support for low-carbon industries is more limited. Likewise, evidence on technology spillovers and policy diffusion is more fragmented, despite indications that they play a critical role in driving global emission and economic outcomes. Existing literature also often focuses on selected spillovers or transmission channels, centres around a narrow set of mitigation policies—frequently overlooking their design—and limits analysis to particular regions or timeframes. However, as this framework highlights, international spillovers are frequently interconnected and evolve over time, with their scale and direction often shaped by the choice and design of policy instruments. These gaps in the literature underscore the need for a coherent, integrated approach to analysing international spillovers.

By providing this framework, the IFCMA takes a first step toward a more systematic assessment of international spillovers and their implications. Strengthening the evidence base not only provides a basis for more coherent policy-making across countries, but can also help unlock international co-operation to maximise positive spillovers and minimise negative ones, ultimately strengthening and optimising the effectiveness of global climate action.

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