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Improving Economic Efficiency and Climate Mitigation Outcomes through International Co-ordination on Carbon Pricing – Environment Working Paper No. 147

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Table of contents

Tables

Figures

Boxes

Abstract

This paper presents the potential benefits and challenges of enhanced international co-ordination on carbon pricing and outlines the different types and levels of co-ordination that are available for national and sub-national governments. These levels include, inter alia, facilitating new pricing schemes, phasing out inefficient fossil fuel subsidies, sectoral approaches, co-ordination on minimum carbon prices and carbon pricing clubs. Jurisdictions may want to adopt several of these options simultaneously and may co-ordinate at multiple levels of government or across countries and sectors. This creates a bottom-up 'web of carbon pricing schemes', which can be an important element in delivering the Nationally Determined Contributions of the Paris Agreement and which has the potential to support greater levels of climate action and ambition.

Résumé

Ce document présente les avantages et les difficultés potentiels d'une coordination internationale renforcée en matière de tarification du carbone et donne une description des différents types et niveaux de coordination possibles pour les administrations nationales et infranationales. On peut citer, entre autres, la mise en place de nouveaux dispositifs de tarification, l'élimination progressive des subventions inefficientes en faveur des combustibles fossiles, le recours à des approches sectorielles, une concertation concernant une tarification minimale du carbone et l'instauration de clubs de tarification du carbone. Les pays peuvent choisir de mettre en œuvre plusieurs de ces options simultanément et coordonner leurs efforts à différents niveaux d'administration ou bien à l'échelle de pays et de secteurs. Il en résulte un réseau décentralisé de dispositifs de tarification du carbone, qui peut jouer un rôle important aux fins de mettre en œuvre les contributions prévues déterminées au niveau national dans le cadre de l'Accord de Paris, et qui peut contribuer à accroître l'action et l'ambition en faveur du climat.

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All errors and inconsistencies remain the responsibility of the author.

Executive Summary

International co-ordination on carbon pricing can provide significant mutual benefits for co-operating jurisdictions, economically (efficiency gains, more equal playing field), environmentally (safeguarding environmental integrity), and politically (more robust political support). By contributing to more cost-effective mitigation, co-ordination can therefore support greater levels of action and ambition. This paper sets out different options for enhanced co-ordination and coherence:

- **Facilitating the implementation of new carbon pricing schemes** can increase the number of carbon pricing schemes. This can result in a virtuous cycle, encouraging other jurisdictions to implement some form of carbon pricing and raising the ambitions of jurisdictions with existing pricing schemes.
- **Facilitating the implementation of internal carbon price** for the evaluation of public investment projects can ensure that climate considerations are taken into account in those sectors not subject to an external carbon price.
- **Phasing out inefficient fossil fuel subsidies** can correct misaligned price signals and discourages wasteful consumption of fossil fuels, thereby facilitating the transition to a low-carbon economy. It further frees up scarce fiscal resources that could be used more efficiently elsewhere.
- **Sectoral approaches** can mitigate sector-specific greenhouse gas (GHG) emissions while addressing competitiveness and development concerns. Focusing on a specific sector may facilitate agreement on climate action and result in hmore ambitious approaches and broader participation, including by countries without economy-wide climate policies.
- **Climate crediting mechanisms or offsets** can reduce the abatement cost for emitters and transfer financial means for climate actions to sectors outside the carbon pricing schemes, although it may lower the effectiveness. Raising quality standards of offsets and robust accounting standards to avoid double counting can safeguard environmental integrity.
- **Co-ordinating on minimum carbon prices** - for carbon taxes, emission trading schemes (ETS) or excise taxes for fossil fuels - yields economic benefits and strengthens the price signal, thereby increasing certainty for investments in low-carbon technologies. Minimum prices do not prevent jurisdictions from imposing higher effective carbon rates.
- **Direct linking of ETSs** can maximise the economic benefits through full convergence of the carbon price across linked markets, but requires high levels of co-ordination. It can also increase the liquidity of a market, lock-in commitment and send a political signal to internal and external stakeholders. Linking ETSs involves mutual agreement on political choices, including on the relative stringency of the cap and cost-containment measures.
- **Carbon pricing clubs and carbon markets clubs** can realize economic benefit beyond the benefits deriving from price convergence and can encourage participation of jurisdictions by employing complementary, but potentially controversial, measures such as border carbon adjustment or uniform trade tariffs.

Co-ordination is not one-dimensional, but may involve jurisdictions adopting multiple co-ordinating options simultaneously at multiple levels. Though the options above are set out broadly in order of the depth and extent of co-ordination required, there is no presumption that any jurisdiction's mitigation journey should progress linearly. Jurisdictions may wish to adopt one or more of these options simultaneously and may co-ordinate at multiple levels, e.g. involving different levels of government or both across countries and across sectors. The emergence of such a bottom-up 'web of carbon pricing schemes' may be an important element in delivering the NDCs and achieving the Paris mitigation goals. An incremental approach on co-ordinating carbon pricing, thus, seems to have the potential to create and maintain political momentum for deeper co-ordination and more stringent mitigation action.

1. Introduction

The Paris Agreement calls for 'holding the increase of the global temperature to well-below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (UNFCC, 2015[1]). Holding the temperature increase below 1.5°C instead of 2°C would avoid more severe damages from climate change (IPCC, 2018[2]). Governments put forward mitigation pledges, known as Nationally Determined Contributions (NDCs), but when all NDCs were implemented, they would be insufficient to meet the well-below 2°C target.

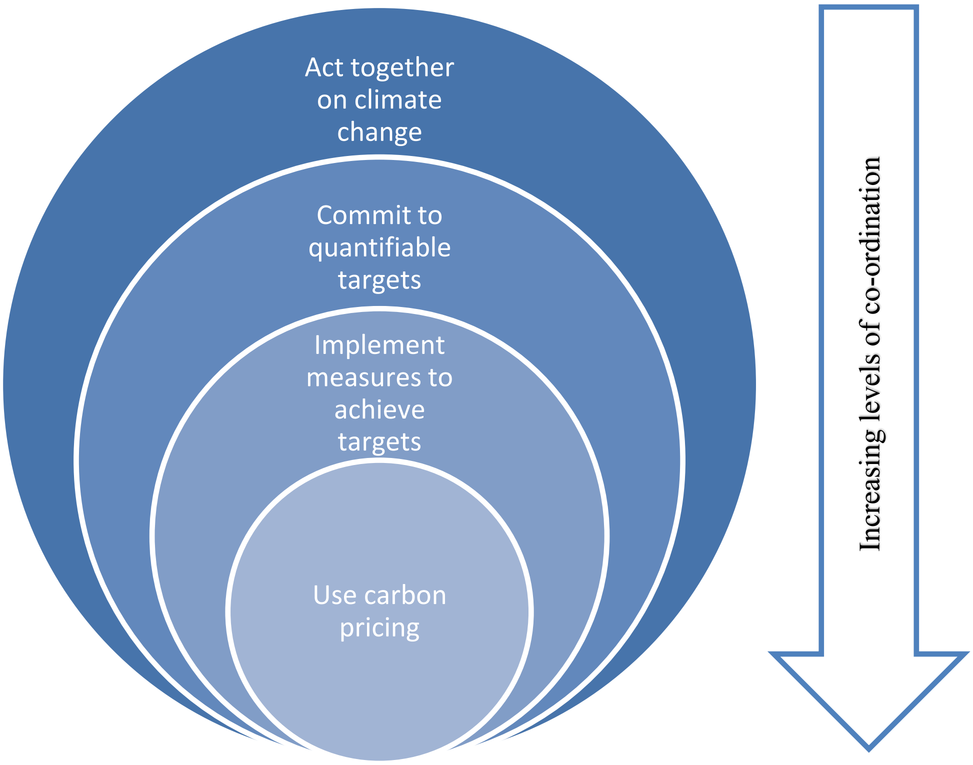
International co-operation can help to keep the global temperature increase below 2°C. Mitigating climate change has the character of a public good that can result in free-rider incentives of national governments. Each jurisdiction has an incentive to contribute a lower amount to the public good relative to the global optimum, but international co-operation can address these misaligned incentives (Carraro and Siniscalco, 1993[3]). There are different forms of international co-operation on climate change that vary in their depth of required co-ordination, including committing to quantifiable targets as in the Paris Agreement and co-ordination on carbon pricing (Figure 1.1).

Meeting the 2°C target requires a decisive transition towards a low-carbon economy. For this transition to happen, governments can apply a wide range of climate policies, including carbon pricing (OECD, 2017[4]). 88 out of 155 NDCs, covering 56% of global greenhouse gas (GHG) emissions, plan or consider using international or domestic carbon pricing instruments (World Bank and Ecofys, 2018[5]).

Pricing carbon emissions, through taxes or emission trading schemes (ETS), is the building block of any climate policy package as it encourages emitters to seek cost-effective abatement options. Putting a price on carbon can give private actors an economic incentive to reduce GHG emissions, to channel investments into low-carbon technologies, and to spur innovation to find cheaper and better ways of reducing emissions (OECD, 2015[6]). Reducing GHG emissions can bring co-benefits, including health benefits due to lower levels of local air pollution, while carbon pricing can improve the efficiency of the tax system by generating revenues that allow for reducing distortionary taxes elsewhere in the economy.

Carbon pricing schemes have gained momentum in the last years, but coverage and price levels are still too low to reach the goals of the Paris Agreement. As of 2018, there are 45 national and 25 subnational carbon pricing schemes, covering around 20% of global GHG emissions (World Bank and Ecofys, 2018[5]). When accounting for excise taxes on energy use, 54% of energy-related carbon dioxide (CO2) emissions are facing a positive carbon price based on data from 42 OECD and G20 countries covering about 80% of energy-related CO2 emissions (OECD, 2018[7]). However, only 12% of emissions, notably in the road sector, are priced above 30 Euros per ton CO2, a midpoint of the medium term price range consistent with the well-below 2°C target (High-Level Commission on Carbon Prices, 2017[8]).

Figure 1.1. Typology of co-ordination on climate change



Source: Author modified from (Climate Strategies, 2016[9])

Co-ordination on carbon pricing can yield mutual benefits and therefore can help jurisdictions to increase both the domestic coverage and levels of emission pricing, eventually leading to higher mitigation ambition. These benefits (discussed in more detail in section 3 of this paper) include:

- Economic benefits in terms of efficiency gains due to convergence of carbon prices across jurisdictions. Price convergence also levels the playing field, particularly for energy-intensive trade-exposed sectors.
- Environmental benefits through co-ordination on enhanced quality standards for emission allowances, including carbon credits, and on robust accounting standards to avoid double counting and safeguard environmental integrity.
- Political benefits in terms of signalling commitment to domestic and foreign stakeholders, thereby reducing policy uncertainty for households and firms. The political signal may also spill-over to other regions, encouraging a wider adoption of climate policy and carbon pricing there. Voluntary, stepwise and incremental approaches to international co-ordination can maintain political momentum and build trust among jurisdictions, thereby reinforcing countries' ambition.

Co-ordination on carbon prices faces barriers that may hamper effective co-operation. Jurisdictions may vary in the degree of political ambition towards climate mitigation action, reflecting country-specific preferences. Moreover, price convergence as a result of co-ordination can lead to undesirable distributional consequences, including a shift of the burden of climate action to low-income countries, and regional shifts of co-benefits from climate mitigation, both of which need to be taken into account and properly addressed.

This report sets out the levels, challenges, and potential roadmaps towards more international co-ordination on carbon pricing. Section 2 discusses the major advantages of carbon prices and informs about current carbon pricing initiatives, highlighting the role of energy-related taxes. Section 3 reviews the major benefits of and barriers to deeper co-ordination across jurisdictions. The fourth section discusses in detail different levels of co-ordination, roughly ordered according to the required depth of co-ordination, and presents existing initiatives and efforts. Section 5 summarizes the lessons learnt from existing initiatives and sketches the roadmaps towards deeper co-ordination that would lead to more ambitious carbon pricing.

2. Carbon Pricing: Importance and existing initiatives

Carbon prices can result from different instruments, including taxes, ETSs and crediting mechanisms. While emitters pay a constant rate for each ton of GHG emissions - measured in equivalent CO_2 (CO_2e) - under a carbon tax, a carbon price in an ETS emerges through trading or auctioning of allowances. Taxes on energy products put an implicit price on carbon emissions, whereas governmental support for fossil fuels can lead to negative carbon prices. The effective carbon rate (see below) combines carbon prices resulting from market-based instruments, including ETSs, carbon taxes, and taxes on energy products, informing about the total (external) price of CO_2e emissions. Internal carbon prices, e.g. for evaluating public investment projects complement external prices. Crediting mechanisms –such as the Clean Development Mechanism (CDM) – allow emitters to offset some emissions by purchasing project-based emission reduction certificates.

This section provides an overview of the current state of carbon pricing. First, it briefly illustrates the importance of carbon pricing, explaining why carbon prices are a necessary instrument for the transformation to a low-carbon economy. Second, it reviews the current carbon pricing landscape, highlighting recent developments and emerging carbon pricing schemes. Third, based on the concept of effective carbon rates, this section illustrates that the overall level of carbon pricing is still too low to be consistent with the Paris Agreement while carbon rates differ considerably both between countries and between economic sectors, indicating that co-ordination of carbon pricing can yield substantial benefits.

2.1. The importance of carbon pricing

Carbon pricing is the cornerstone of every climate policy package. Carbon prices have at least three desirable properties making it the single most important instrument to tackle climate change.

- Carbon prices are a cost-effective instrument. Emitters of GHG emissions will reduce emissions as long as the costs associated with the emissions reduction, i.e. the marginal abatement costs, are smaller than paying the carbon price. A uniform carbon price, thus, equalises the marginal costs of reducing emissions across all emitters in an economy, so that the aggregate abatement cost is minimised (OECD, 2016[10]).
- Carbon prices can exploit the private information of economic agents and, thus, can decentralise abatement decisions. Firms and households usually have better information on the available abatement options and the respective costs than the government. Carbon prices exploit this information by allowing firms and agents to choose the option that is most suitable for them, thereby decentralising the abatement decision. This is more cost-effective than a regulatory approach in which the government prescribes which emissions should be reduced in which sector and through which abatement technology.
- Carbon prices can channel investments into low-carbon technologies while spurring innovation and development of these technologies by providing ongoing incentives to reduce emissions. New clean technologies are an important element of reducing future GHG emissions at a lower cost. The empirical literature suggests

a positive relationship between carbon prices and innovation in low-carbon technologies (Calel and Dechezleprêtre, 2016[11]).

All carbon pricing instruments need mechanisms that enable governments to raise ambition over time. Transparent and long-term price signals, e.g. through announcement of long-term carbon tax trajectories or emission reduction paths, increase credibility, and ultimately help spurring investments into low-carbon technologies by reducing investment uncertainty. However, carbon prices also need to be flexible to adjust for external shocks and new (technological) developments that may result in lower than expected abatement costs. Hence, policy makers need to carefully review the level of carbon prices on a regular basis and balance the price trajectory between credibility and flexibility.

While being the single most important instrument for addressing climate change, carbon pricing alone may not be sufficient to deliver the transformation necessary for meeting the 2-degree target of the Paris Agreement. Other market failures and barriers – e.g. technological spill-overs, information asymmetries, and split incentives - can prevent carbon pricing from reducing GHG emissions in the most cost-effective way. These market failures need to be properly addressed by complementary policies, including specific investment incentives (e.g. for research and development), standards and mandates (e.g. fuel or energy efficiency standards), and information instruments (e.g. energy labelling).

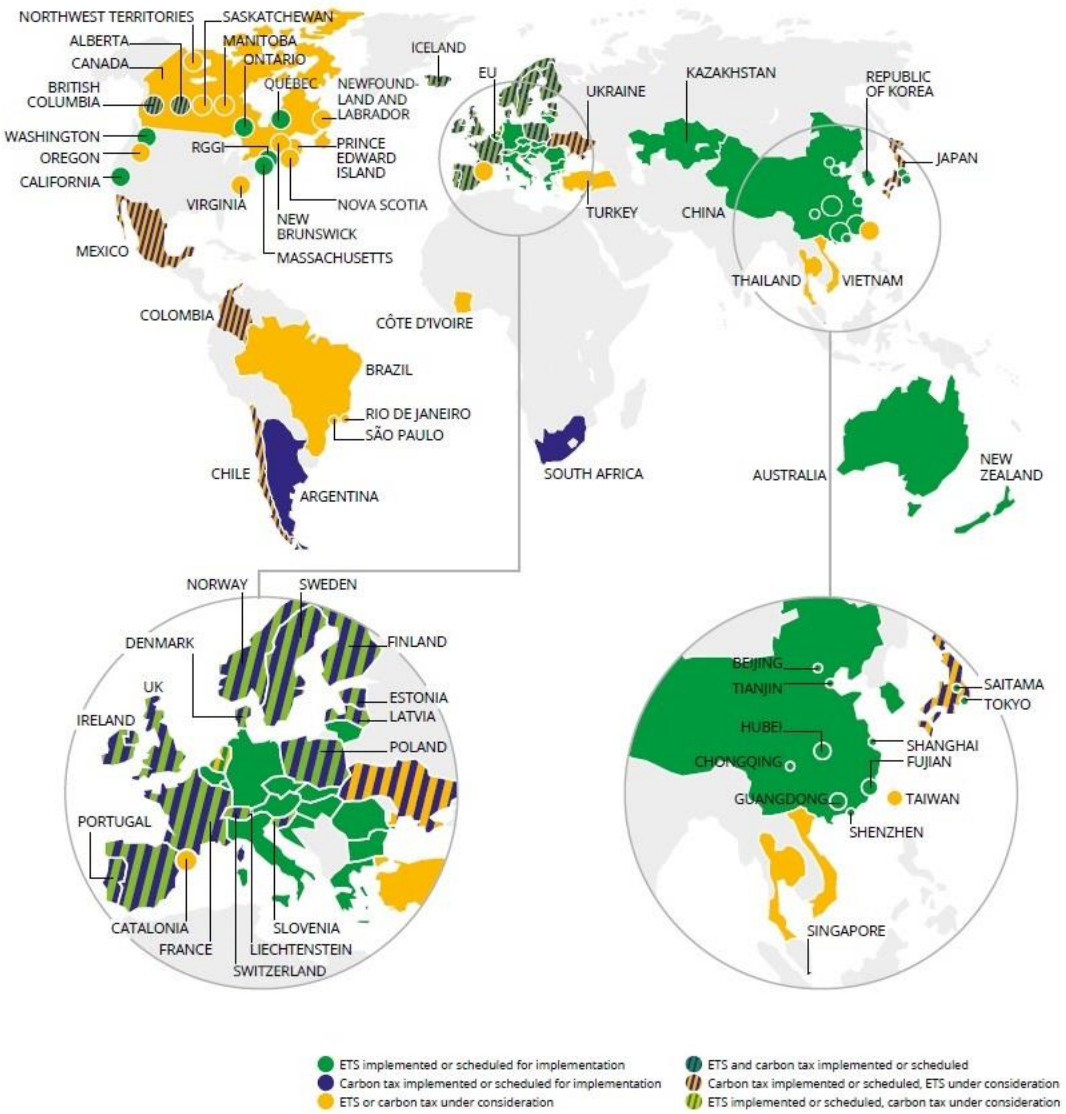
Combining carbon pricing with complementary policies has the potential of mitigating a given amount of CO_2 emissions at lower economic costs. For example, the combination of carbon pricing with innovation policies for low-carbon technologies can reduce emissions and lower the associated economic costs (Acemoglu et al., 2012[12]). The underlying reason is that the advancement of existing and the discovery of new low-carbon technologies may require an excessively high carbon price to trigger private investment into research and development. This is particularly true for low-carbon breakthrough technologies (e.g. carbon capture and storage) with high up-front cost and low probability of discovery. Support for basic research and development may facilitate the discovery of these technologies, thereby requiring a lower carbon price for compensating private research and development efforts. Moreover, creating knowledge in general, and developing low-carbon technologies in particular, has the character of a public good, meaning that private actors may under-invest in knowledge creation from a social point of view.

Climate policy should take the interactions between the carbon price and the complementary measures into account. These interactions are also influenced by the type of the carbon pricing instrument, i.e. whether countries have implemented a carbon tax or an emissions trading scheme. There are pros and cons for both instruments and countries must choose which instrument fits best to their policy package and the country-specific circumstances (Goulder and Schein, 2013[13]).

2.2. The current carbon pricing landscape

Many national and sub-national governments are planning to or have already implemented some form of carbon pricing. In the Paris Agreement, 88 out of 155 Parties have stated in their NDCs that they are planning or considering the use of carbon pricing to meet their GHG mitigation targets. Taken together these Parties account for around 56% of global GHG emissions and include some of the biggest GHG emitting countries such as China, India and Japan (World Bank and Ecofys, 2018[5]). As of 2018, carbon prices have been introduced by 45 jurisdictions on a national and 25 jurisdictions on a sub-national level (Figure 2.1) The existing initiatives cover around 11 Gt CO_2e equivalent to 20% of global annual GHG emissions. In 2017, government revenues from auctioning permits and carbon tax receipts amounted to USD 33 billion (World Bank and Ecofys, 2018[5]).

Figure 2.1. Existing and scheduled carbon pricing schemes on national and sub-national levels



Source: (World Bank and Ecofys, 2018[5])

The coverage and price levels across carbon pricing schemes vary substantially. While the Polish and Estonian carbon tax covers around 5% of domestic GHG emissions, this figure is 85% for the ETSs in Quebec and California. There is also substantial heterogeneity of carbon prices across countries with carbon rates varying from <1 USD/t CO_2e in Poland and the Ukraine to as high as 139 USD/t CO_2e in Sweden (World Bank and Ecofys, 2018[5]).

Carbon pricing has gained particular momentum in the last years**.** More than half of the currently existing initiatives have been implemented in the last six years. Table 2.1 provides an overview of some initiatives launched between 2015 and 2018. Carbon taxes on a national level have been implemented by France (2014), Mexico (2014), Portugal (2015), Chile (2017), Colombia (2017). The pan-Canadian approach, adopted in 2016, establishes a federal benchmark to ensure that a minimum price of initially CAD 10 is in place in all jurisdictions in Canada by 2018[1] (Environment and Climate Change Canada, 2016[14]). ETSs have been launched in Kazakhstan (2013)[2], South Korea (2015), and China (2017). The Chinese ETS was launched officially in December 2017, and is expected to become operational in 2020 (World Bank and Ecofys, 2018[5]). During the One Climate Summit in 2017, government leaders of some national and sub-national governments in the Americas[3] expressed their commitment to carbon pricing and highlighted the importance of regional co-operation in the 'Paris Declaration on Carbon Pricing in the Americas' (UNFCCC, 2017[15]).

Table 2.1. Emerging carbon pricing initiatives in the last four years

Country/region	Year	Instrument	Point of Regulation	Coverage	Price in USD/t CO_2
Alberta	2017	Tax	Upstream	Gasoline, diesel, natural gas, propane and other energy products not covered by Alberta ETS	30
Australia	2016	ETS*	Downstream	Large emitters with >100kt CO_2e per year	Na
Chile	2017	Tax	Downstream	Electricity generators and other large emitters with >50 MWe	5
China	2017	ETS**	Downstream	Power sector (including CHP) facilities with >26kt CO_2e/year	Na
Colombia	2017	Tax	Upstream	Energy products	5
Fujian (China)	2016	ETS	Downstream	Electricity, petrochemical, chemical, building materials, iron and steel, nonferrous metals, paper, aviation, ceramics	5**
Korea	2015	ETS	Downstream	23 subsectors (e.g. power, buildings, manufacturing, waste and aviation)	18**
Massachusetts	2018	ETS	Downstream	Electricity generators with >25MWe	Na
Ontario	2017	ETS	Downstream	Electricity, transport fuel distributors and industrial facilities with >25kt CO_2e/year	15**
Portugal	2015	Tax	Upstream	Gasoline, diesel, natural gas and other energy products not covered by EU ETS	8

Note: * Australia's ETS (the safeguard mechanism of the Emission Reduction Fund) is a baseline-and-offset system. It requires Australia's largest emitters to keep emissions within baseline levels, but allows for offsetting emissions in excess through financing emissions reductions of projects elsewhere in the economy.
** Prices for ETS reflect average annual spot prices in 2017.
Sources: (Australian Government, 2014[16]), (Government of Alberta, 2017[17]), (ICAP, 2018[18]), (World Bank, Ecofys and Vivid Economics, 2016[19]), (World Bank, Ecofys and Vivid Economics, 2017[20]), (World Bank and Ecofys, 2018[5]).

Existing initiatives have broadened their coverage geographically, sectorally and in terms of GHG coverage while some initiatives have announced more ambitious carbon prices:

- Geographic coverage: After the non-EU members Norway, Iceland, and Liechtenstein joined the EU ETS in 2008, Croatia became a new member with the

[1] In addition to its pre-existing carbon tax, British Colombia launched an ETS in 2016, while Alberta and Ontario implemented a carbon tax and an ETS in 2017, respectively.
[2] While the Kazakhstan ETS was temporarily suspended in 2016, it restarted operation in 2018 (ICAP, 2018[133]).
[3] These government leaders include Canada, Chile, Colombia, Costa Rica, México, the Governors of California and Washington, as well as the Premiers of Alberta, British Columbia, Nova Scotia, Ontario and Quebec.

beginning of the third trading phase (2013 – 2020), taking the number of countries to 31.

- Sectoral coverage: The EU ETS expanded its sectoral scope with domestic aviation becoming regulated from 2012 and aluminium, carbon capture and storage, petrochemicals, and chemicals being included from 2013.
- GHG emissions: The EU ETS covers from 2013, in addition to CO_2, nitrous oxide (N2O) emissions from the chemical sector and perfluorocarbons (PFCs) from the aluminium sector.
- Level of pricing: To address the oversupply of permits in the third phase, the European Commission revised the emission reduction factor, which linearly reduce the cap in each year, from 1.74% to 2.2% starting in 2021 and introduced the Market Stability Reserve that allows for reducing the supply of permits depending on the amount of permits in circulation. The UK unilaterally implemented a carbon floor price for installations in the power sector that started at GBP 9 per ton CO_2e in 2013, was intended to reach GBP 30 by 2020, but was capped at GBP 18 in 2016 (Hirst and Keep, 2018[21]). California introduced an auction reserve price of USD 14.53 per ton CO_2e in 2018, which is going to increase annually by 5% plus inflation while Quebec (linked to the California ETS) established a reserve price of CAND 14.35 (USD 18.63) (ICAP, 2018[18]).

In the coming years, the trend of establishing new pricing schemes, and increasing the coverage and price levels of existing schemes will continue:

- New schemes: Singapore intends to introduce a carbon tax of between 7–15 USD/tCO_2e by 2019. New carbon markets are scheduled to launch in Mexico, Ukraine as well as Virginia, and are under consideration in Brazil, Chile, Colombia, Japan, Turkey, Thailand, Viet Nam as well as in the U.S. states New Jersey, Oregon, and Washington State (World Bank and Ecofys, 2018[5]).
- Sectoral coverage: British Colombia intends to include fugitive emissions as well as emissions from the burning of forestry residues.
- Price level: The EU ETS, Korea ETS, and the Chinese Pilot Fujian will strengthen the price stabilization mechanism to increase the market price of permits. Similarly, carbon taxes will be raised in Iceland, Switzerland, and British Colombia, whereas Sweden will revise its tax breaks for installations covered under the EU ETS.

2.3. Getting the full picture: Effective carbon rates

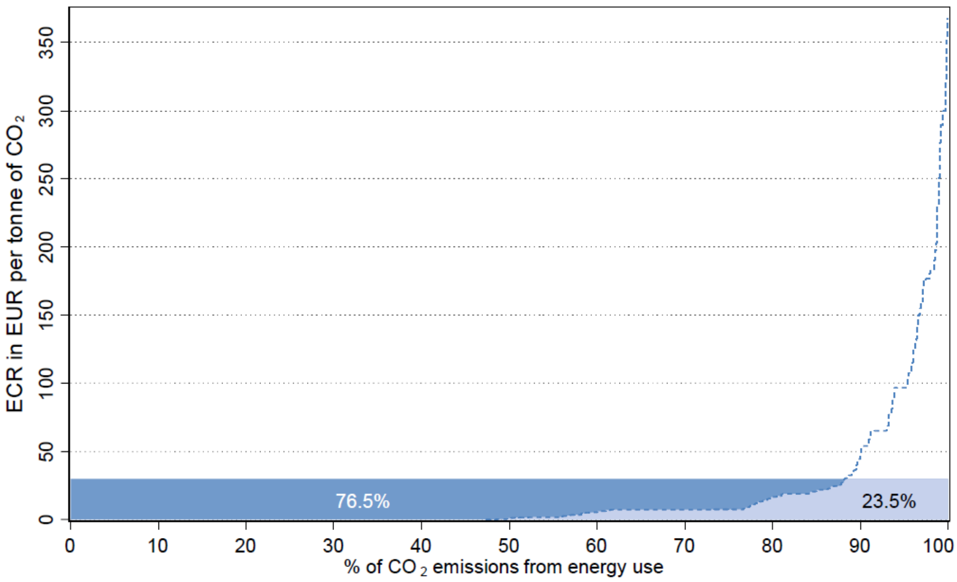
Taxes on energy use also put a price on carbon and need to be taken into account to draw a more comprehensive picture of the carbon pricing landscape. Pre-existing domestic energy-related taxes such as taxes on gasoline, diesel, coal, or electricity already put an implicit price on fossil fuels and on carbon emissions.

Effective carbon rates (ECRs) are the sum of carbon taxes, emissions permit prices, and specific taxes on energy use, expressed in EUR per tonne CO_2 emissions (OECD, 2016[22]). They are the price on carbon emissions that the end user of energy products faces as a result of market-based policies. Excise taxes on energy use account for the largest part of effective carbon rates. For example, 99% of the ECR in the transport sector can be attributed to energy taxes. Energy taxes may be an instrument to address externalities other than climate change, including congestion, noise, and local air pollution.

The effective carbon rates are too low to provide the right incentives for climate change mitigation. Based on data from 42 countries from 6 sectors (industry, electricity generation, residential and commercial energy use, road transport, off-road transport, and agriculture and fisheries), covering 80% of global carbon emissions from fossil fuel combustion, OECD (2018[7]) finds that 46% of CO_2 emissions is not priced at all. Moreover, only 12 % of emission are priced above EUR 30, which roughly corresponds to the low-end estimate for the costs of carbon suggested by the High Level Commission on Carbon Pricing (2017[23]) for 2020.[4]

The carbon pricing gap is too large, but has been declining, albeit at a slow pace. The carbon pricing gap measures the difference between actual ECRs and EUR 30 and indicates the extent to which polluters do not pay for the damage caused by carbon emissions. While the pricing gap was 83% in 2012, it is estimated to reach 76.5% in 2018 (Figure 2.2). This corresponds to an average reduction of 1 percentage point in each year – too slow for a cost-effective decarbonisation of the economy.

Figure 2.2. The carbon pricing gap and the distribution of effective carbon rates

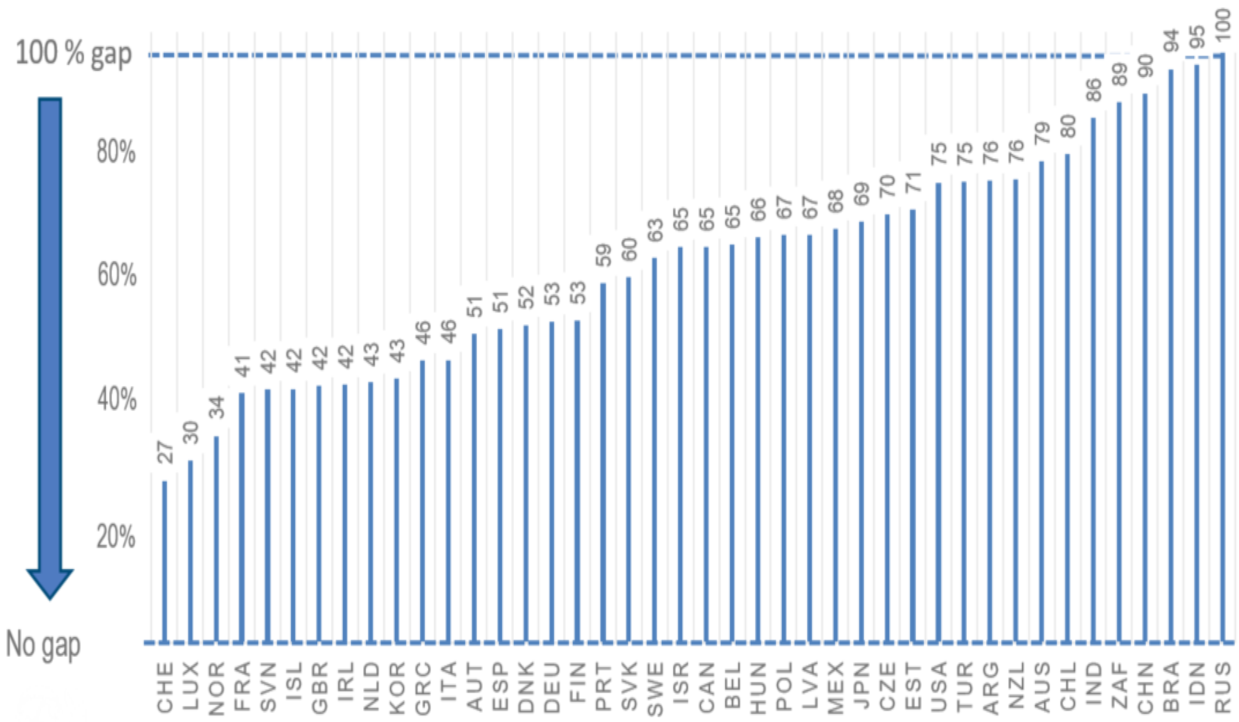


Source: (OECD, 2018[7])

The carbon pricing gap varies considerably across countries. The pricing gap varies from 100% in Russia to 27% in Switzerland (Figure 2.3). While many European countries have carbon pricing gaps around or even below 50%, emerging economies such as BRICS countries have rather large gaps that are above 89%. Cross-country variation of carbon pricing gaps may be rooted in the heterogeneity of price levels between jurisdictions, indicating large potentials for economic benefits from co-operation.

[4] The High Level Commission on Carbon Pricing reports that carbon prices should amount to USD 40 - 80 per tonne of CO_2 by 2020 and to USD 50 - 100 per tonne of CO_2 by 2030 to be consistent with reaching the goals of the Paris Agreement.

Figure 2.3. Carbon pricing gap differs across countries



Source: (OECD, 2018[7])

The coverage of CO_2 emissions by carbon pricing instruments differs substantially between economic sectors. While only 22% of the emissions from residential and commercial heating are priced at a positive effective carbon rate, 97% of road transport emissions are subject to some market-based policy instrument (Figure 2.4)**.** Moreover, almost half of the emissions in the road sector are priced above EUR 60, a midpoint estimate of the carbon costs in 2020. However, this does not mean that ECRs in road transport are excessively high, but rather points to the fact that excise taxes on petroleum and diesel (that account for 99% of the ECR in the road sector) are also internalizing other transport-related externalities. Based on evidence from France and UK, these taxes seem to be in line with the marginal external costs from noise, accidents and local air pollution (OECD, 2018[7]).[5]

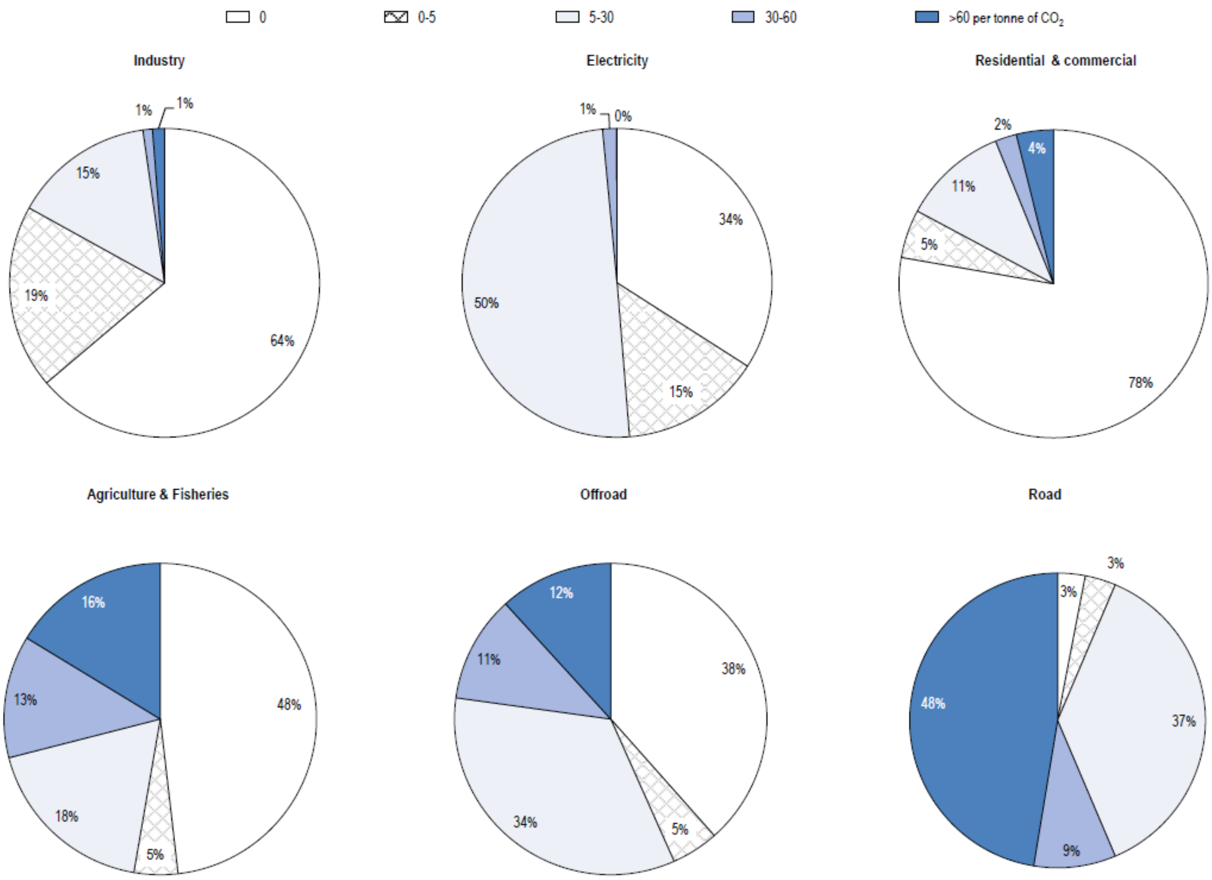
Carbon prices are particularly low in sectors that predominantly influence the international competitiveness of the domestic economy. Taking the benchmark carbon price of EUR 30, Figure 2.4 reveals that only 1% of emissions in the electricity sector and 2% of emissions in the industry sector are priced above EUR 30. While carbon prices in the industry sector have a direct effect on the production costs of energy-intensive industries, high ECRs in the electricity sector impact productions costs indirectly through potentially higher electricity prices. Thus, co-ordination on carbon pricing in these sectors, including through

[5] The ECRs in road transport would be too low, when accounting for congestion. However, fuel taxes are not well suited for internalizing the external costs of congestion. Instead, direct congestion charges are a superior instrument to address congestion (Van Dender, 2018 forthcoming[117]).

sectoral approaches (see Section 4.4), may have large impacts on the levels of carbon prices and on the consistency across sectors, thereby enhancing cost-effectiveness.

Figure 2.4. Proportion of effective carbon rates by sector

Price levels in EUR per tonne of CO_2



Source: (OECD, 2018[7])

To conclude, the main insights include:

- Carbon pricing is the single-most important policy instrument to address climate change mitigation. Carbon prices are a cost-effective instrument that elicit firms and households to seek cost-effective abatement options, and spur innovation of low-carbon technologies.
- Carbon pricing schemes have been emerging and will continue to emerge all over the world, thereby increasing the global coverage of GHG emissions. Existing carbon pricing schemes both expand their coverage in terms of GHG emissions and sectors while aiming at increasing the price levels in some cases.
- Effective carbon rates (ECRs) inform about the price on carbon derived from cost-effective price-based instruments, including carbon taxes, allowance prices and excise taxes on energy products. The carbon pricing gap indicates the gap between

the ECR and EUR 30, a low end estimate for the social cost of climate change by 2020.

- The carbon pricing gap is closing, but the speed is too slow to be consistent with reaching the price levels necessary to meet the goals of the Paris Agreement.
- The carbon pricing gap varies considerably between countries, indicating large potential for savings in mitigation costs from international co-ordination.
- ECRs differ substantially between sectors, challenging the cost-effectiveness of the current carbon and energy policies. ECRs in economic sectors that impact the international competitiveness of the economy tend to be particularly low.
- Greater consistency on carbon pricing within countries and co-ordination across countries would help achieve emissions reductions in a more cost-effective way. This would allow countries to raise both the level of their mitigation ambition and of the prices of current pricing schemes while expanding the coverage of the schemes.

3. Benefits of and barriers to co-ordination on carbon pricing

Enhanced international co-ordination between the bottom-up carbon pricing schemes brings benefits, but also involves barriers that need to be addressed. Currently, there are many different carbon pricing schemes at different levels of government, using different instruments – carbon taxes, emissions trading schemes and energy related taxes. However, both the coverage and the price levels of these schemes are not sufficient to be consistent with holding global warming below 2°C (Section 2). Moreover, carbon prices vary considerably between countries and between economic sectors, indicating large potential for economic benefits from co-operation.

This section briefly reviews the major benefits from international co-ordination (economic, environmental, political, and fiscal). It also discusses potential barriers to co-ordination (competiveness concerns relative to third party countries, interaction with existing energy taxes, undesirable distributional consequences, loss of co-benefits).

3.1. Benefits from co-ordination

Co-ordination on carbon pricing can yield mutual benefits and therefore can help jurisdictions to increase both the domestic coverage and level of emission pricing, eventually leading to higher mitigation ambition. These benefits include i) economic benefits in terms of efficiency gains due to convergence of carbon prices across jurisdictions and levelling the playing field; ii) environmental benefits through co-ordination on enhanced and robust quality standards for emission allowances; iii) political benefits in terms of signalling commitment to domestic and foreign stakeholders; and iv) fiscal benefits in terms of more fiscal space for governments as a result of higher price levels.

3.1.1. Economic benefits

International co-ordination on carbon pricing can increase economic efficiency and reduce aggregate abatement costs through the convergence of carbon prices. Emitters of GHG emissions abate emissions until their marginal abatement costs equal the carbon price. Convergence of carbon prices across jurisdictions leads to a convergence of marginal abatement costs, meaning that the same amount of emissions can be reduced at a lower cost. However, the benefits of savings in mitigation costs may not be shared equally across co-ordinating partners.

The savings in mitigation costs associated with a global carbon market can be as high as 30% by 2030, equivalent to cumulative savings of around USD 115 billion (World Bank, Ecofys and Vivid Economics, 2016[19]). Based on the assumption that all countries comply with their NDCs form the Paris Agreement by 2030, World Bank, Ecofys and Vivid Economics (2016[19]) compare a scenario in which each country meets its target domestically with a scenario where emissions certificates are traded internationally starting from 2020. International carbon trading allows countries with high marginal abatement costs to finance emission reductions abroad where the costs are lower. The carbon market scenario involves substantial cross-country transfers of both emission certificates and financial resources, amounting to around 2.5 Gt CO_2e traded certificates worth USD 185 billion. According to the simulation, developed countries (except Canada and Australia) and China will be permit buyers while emerging and developing countries will be permit sellers. Less deep co-ordination of carbon prices will also yield savings of mitigation costs, albeit at a smaller order of magnitude.

Co-ordination of carbon prices across jurisdictions can also level the playing field and reduce the risk of carbon leakage. Carbon leakage refers to an increase of carbon emissions in one jurisdiction as a result of climate policy, particularly carbon pricing, in another jurisdiction (Felder and Rutherford, 1993[24]). Differences in carbon prices across regions can put energy-intensive firms in the high price region at a comparative disadvantage, eliciting these firms to reduce their output or to move part of the production to regions with less stringent climate policies. This can involve substantial welfare losses in terms of job losses and a reduced industrial base. Moreover, carbon leakage reduces the environmental effectiveness of unilateral carbon pricing schemes due to higher emissions abroad, thereby potentially limiting the domestic political support for unilateral measures. Any co-ordination of carbon prices that leads to some price convergence reduces the comparative disadvantage of energy-intensive firms and, thus, the risk of carbon leakage.

The risk of carbon leakage is confined to a certain subset of sectors, but the empirical evidence is rather weak. Carbon leakage is most likely to be relevant in energy-intensive trade-exposed (EITE) sectors such as aluminium, cement, and steel. Carbon prices have a large impact on the production costs in these sectors while the exposure to trade implies high competitive pressure from foreign firms (Reinaud, 2008[25]). However, the empirical evidence for carbon leakage is rather weak with many studies concluding that current climate policies have not had a detrimental impact on firms' competitiveness (Dechezleprêtre and Sato, 2017[26]). However, this may be due to complementary measures (e.g. tax exemptions and allocation of free allowances) to curb the risk of carbon leakage and due to relatively low actual levels of carbon prices. In fact, the low price levels might be a result of concerns about the impact of higher carbon prices on the competitiveness of the domestic industry. If the differences of carbon prices between jurisdictions rose, then the risk of carbon leakage would increase and the conclusions from the empirical literature may not hold true anymore.

3.1.2. Environmental benefits

International co-ordination on carbon pricing can bring environmental benefits in terms of safeguarding environmental integrity. This is particularly relevant for trading of emission allowances between jurisdictions. Some carbon credits and projects, including those from the Clean Development Mechanism, seemed to have weak quality standards, questioning whether and to what extent they actually reduced GHG emissions (Wara, 2007[27]). Reasons for weak quality standards include the application of weak methodologies regarding baseline estimations and quantification of emission reductions as well as doubts concerning the additionality of projects, i.e. whether projects actually lead to emissions reductions that are additional to those that would have taken place anyway (Zhang and Wang, 2011[28]). Robust quality standards form the basis of international emissions and offset trading as they create confidence for investors and jurisdictions that emissions reductions are indeed happening. Hence, co-ordination on guidelines for enhanced quality standards for emission allowances and carbon credits can safeguard environmental integrity and, thus, enable deeper co-ordination through international trading of emission allowances. Similarly, robust accounting standards to avoid double counting are also necessary to build trust and safeguard environmental integrity.

3.1.3. Political benefits

International co-ordination on carbon prices can increase the domestic support for more ambitious reduction targets in the future. Carbon prices are a very transparent instrument to measure the ambition of countries' climate policy. If citizens observe that other countries are also contributing their fair share towards mitigating climate change, the domestic support for more ambitious climate policies is likely to increase (Walker and Ostrom, 2003[29]). In addition, the benefits of co-ordinating carbon prices derived from savings in mitigation cost and reduced risk of carbon leakage, further enable policy makers to pursue more ambitious domestic climate policy (Figure 3.1).

Ambitious domestic climate policy due to enhanced domestic support can also spill-over to other regions, encouraging broader climate policy and carbon pricing. Ambitious domestic climate policy can serve as a signal for other countries to be more ambitious as well while higher ambitions in foreign jurisdictions can reinforce domestic support. This process may ultimately result in a virtuous cycle of raising ambitions that may also translate into higher carbon prices (Cramton et al., 2017[30]).

International co-ordination can also yield political benefits in terms of signalling commitment to domestic and foreign stakeholders, thereby reducing policy uncertainty for households and firms. International approaches can create in some cases an institutional lock-in, in the sense that these approaches may be more robust against discretionary policy due to mutual pressure of co-ordinating partners (Flachsland, Marschinski and Edenhofer, 2009[31]). Pulling out from international treaties may be costly in terms of losing (international) political capital, resulting in elevated levels of credibility of international approaches.

Voluntary, stepwise and incremental approaches to international co-ordination can create and maintain political momentum, thereby reinforcing countries' ambition. Each step of international co-ordination sends a signal, indicating that co-operating parties are willing to reciprocate the efforts of their partners while building trust among jurisdictions (Ostrom, 2010[32]). Higher levels of trust are the foundation for enhanced and deeper co-operation, finally increasing the speed of collective action and leading to higher ambition.

3.1.4. Fiscal benefits

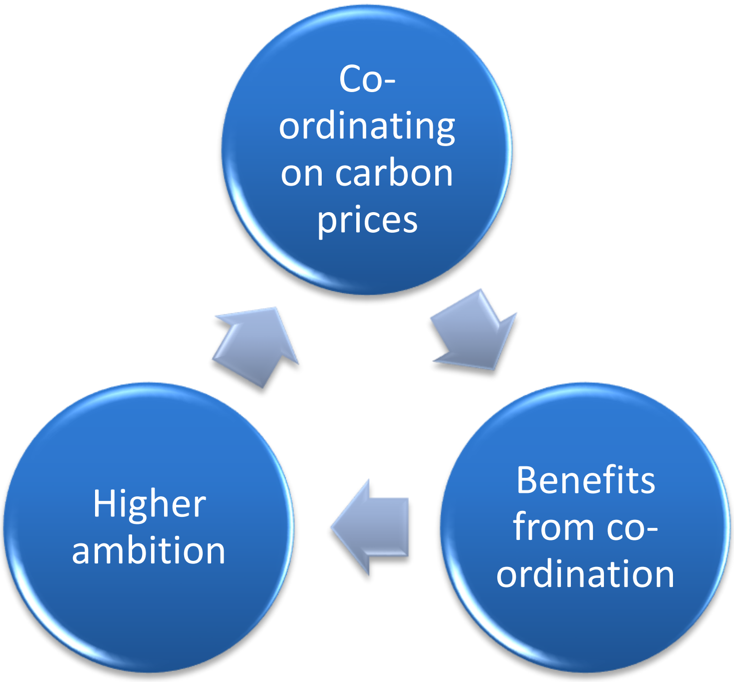
International co-ordination can enable governments to pursue more ambitious carbon pricing policies that in turn can improve governments' fiscal space. By reaping the benefits of co-ordination, in particular through increased political support and reduced adverse effects of unilateral carbon pricing, governments can increase the stringency of carbon pricing policies while relaxing complementary measures such as tax exemptions. Such practices have multiple fiscal benefits (e.g. from auctioning allowances, carbon tax revenues and removing fossil fuel subsidies):

- Reduce distortionary (labour) taxes, thereby increasing the efficiency of the tax and transfer system, promoting employment and economic growth (Goulder, 1995[33]).
- Alleviate the detrimental impacts of carbon prices on the income distribution and on poor households by lump-sum transfers, thereby preventing energy poverty

(Klenert and Mattauch, 2016[34])[6]. For example, Switzerland and the Canadian province of British Colombia redistribute the tax proceeds of the Carbon tax via lump-sum transfers to all households.

- Increase the public acceptance of carbon pricing through redistributing tax revenues by lump-sum transfers as shown by polls from British Colombia (Murray and Rivers, 2015[35]). Although lump-sum transfers are economically not as efficient as reducing distortionary taxes, they tend to be more salient, thereby increasing the public acceptance and the public support for higher taxes in the future.
- Finance public goods such as investments in infrastructure, education and health (Franks, Edenhofer and Lessmann, 2015[36]; Jakob et al., 2016[37]).

Figure 3.1. Co-ordinating carbon prices leads to higher ambition



Source: Author

3.2. Barriers to co-ordination on carbon pricing

International co-ordination on carbon pricing can face barriers that need to be addressed to reap the benefits associated with co-ordination. These barriers include i) competitiveness concerns relative to third party countries, ii) interaction with existing energy-related taxes, iii) undesirable distributional consequences, and iv) potential loss of co-benefits.

[6] Green taxes, including carbon and energy taxes have been found to be regressive because low-income households spend a relatively large share of their available income on energy goods (Metcalf, 1999[134]).

3.2.1. Competitiveness concerns relative to third party countries

Firms in co-ordinating jurisdictions can face a comparative disadvantage vis-a-vis their competitors in non-coordinating jurisdictions if only a subgroup of jurisdictions successfully co-ordinate on increasing the level of their carbon prices. This can compromise successful co-operation in the first place, which is why any co-ordination on a sub-global level that may result into a regional divergence of carbon prices needs to take competiveness concerns into account. The political consequences of firms and jobs moving to jurisdictions with less stringent climate policies are likely to be substantial, undermining the support for more ambitious carbon policies in the co-ordinating jurisdictions and may easily spill-over to other regions hampering the introduction of more stringent climate policies there. Competitiveness concerns can be addressed by the design of the pricing instruments. For example, EITE industries may be exempted from a carbon tax or may receive certificates free of charge as long as differences in carbon prices remain.

3.2.2. Interaction with existing energy-related taxes

Co-ordination and harmonisation of explicit carbon instruments is challenging due to the heterogeneity of country-specific pre-existing energy-related taxes. These taxes indirectly put a price on carbon and are currently responsible for the largest share of the effective carbon rates (see Section 2). If the level of energy-related taxes in some jurisdictions is already high, then these jurisdictions may not consent to joint explicit carbon pricing instruments that would increase the effective carbon rate even further. This can hamper the international co-operation on carbon prices, but informing co-operating partners on the pre-existing energy policy landscape of potential partners can facilitate successful co-operation.

3.2.3. Undesirable distributional consequences

Convergence of carbon prices across jurisdictions may result in undesirable distributional consequences, particularly if low-income countries would face a similar level of carbon prices than high-income countries. Even though price coherence across regions is desirable from an economic efficiency perspective by enhancing cost-effectiveness, it may not be desirable from an equity perspective. Carbon prices in low-income countries may affect households more drastically than households in rather developed countries. It may aggravate energy poverty and may contribute to the lack of access to energy products for some households, which is particularly relevant for low-income households.

3.2.4. Loss of co-benefits

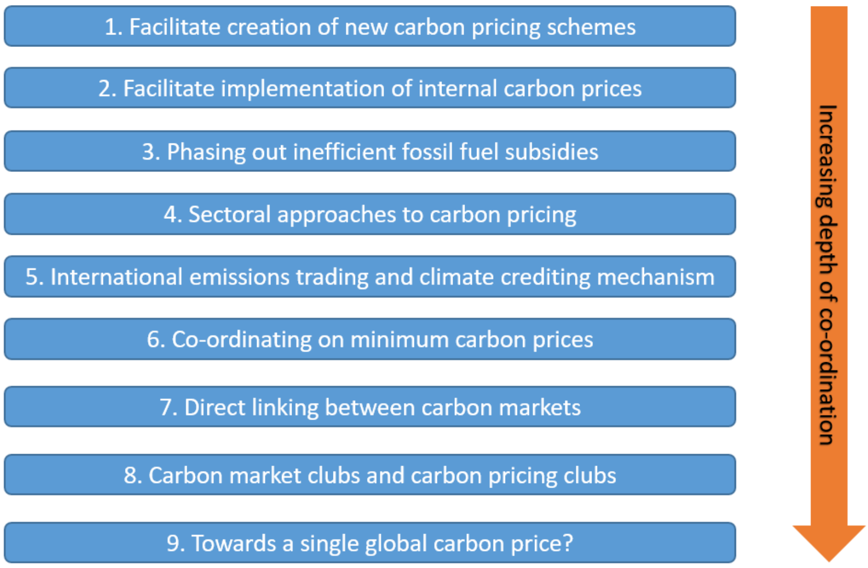
Jurisdictions may experience a loss of co-benefits when co-ordination implies lower actual domestic abatement effort. Reduced domestic abatement may result from international emissions trading, e.g. through crediting mechanisms or linked emissions trading schemes. Reducing GHG emissions, in particular through lowering fossil fuel consumption, is related to a number of other co-benefits, including health benefits due to lower levels of local air pollutants. Outdoor air pollution is responsible for 4.2 million premature deaths per year globally (WHO, 2018[38]). The global welfare costs associated with premature deaths from outdoor air pollution have been estimated at USD 5 trillion in 2015 (Roy and Braathen, 2017[39]), and are projected to increase to USD 15 – 25 trillion by 2060 (OECD, 2016[40]).

4. Levels of international co-ordination on carbon pricing

Carbon pricing schemes are emerging globally, but the current carbon pricing landscape is still highly fragmented. In 2018, there are 51 explicit carbon pricing initiatives that are implemented or scheduled for implementation at all levels of governments: national, sub-national, and city level, covering around 20% of worldwide GHG emissions (World Bank and Ecofys, 2018[5]). This is double the amount than 6 years before. However, the coverage and the price levels differ substantially across jurisdictions (section 2), suggesting that international co-ordination on carbon pricing can bring multiple benefits in terms of improving economic efficiency. Some co-ordination on carbon pricing between several initiatives at different levels is already happening, but more needs to be done to reap the benefits associated with co-ordinating carbon prices. Reaping the benefits, including enhanced economic efficiency, safeguarding environmental integrity and addressing competitiveness concerns, can facilitate higher carbon price levels and broader regional and sectoral coverage of carbon pricing in the future (section 3).

Co-ordination of carbon prices can take different forms that vary in their required depth of co-ordination. Figure 4.1 provides a schematic overview of a range of available options, and indicates the respective section. While these options are ordered according to the depth and extent of co-ordination required, there is no presumption that any jurisdiction's mitigation journey should progress linearly. Jurisdictions may wish to adopt one or more of these options simultaneously and may co-ordinate at multiple levels, e.g. involving different levels of government or both across countries and across sectors, thereby creating a bottom-up 'web of carbon pricing schemes'. This 'web of carbon pricing schemes' can complement the NDCs structure of the Paris Agreement and may be one important element to deliver on the goals of the Paris Agreement in a cost-effective way.

Figure 4.1. Levels of co-ordination



Source: Author

This section describes each of the levels outlined in Figure 4.1 in more detail. It presents the benefits as well as the challenges of each level of co-ordination. For each level, this section also provides real-world examples, if applicable. A summary of the potential and caveats of all options discussed can be found at the end of this section.

4.1. Facilitate the creation of new carbon pricing schemes

Facilitating the implementation of new carbon pricing schemes, either taxes or ETSs, by providing capacity development and sharing practical experience can increase the economic and geographical coverage and eventually the levels of carbon pricing. Increasing the number of carbon pricing schemes can result in a virtuous cycle by encouraging other jurisdictions to implement some form of carbon pricing and by raising the ambitions of jurisdictions with existing pricing schemes.

Providing technical support, building capacity, and other support (e.g. financial) can facilitate and speed up the implementation process of carbon pricing by reducing the technical and political barriers associated with the implementation. Implementing carbon pricing instruments, particularly an ETS, requires multiple technical components, including monitoring, reporting and verification (MRV) of GHG emissions, data management, and registries of regulated entities. Some countries are still lacking the technical capacity and know-how, necessary for introducing well-designed and effective carbon prices. This creates a major barrier for implementing advanced pricing schemes such as ETS. However, national and sub-national governments can share their experience on how to overcome political barriers to carbon pricing in the first place. For example, Belgium launched a national debate on carbon pricing in the non-ETS sectors (e.g. transport and building) that was complemented by a thorough exchange between Belgian and foreign experts from the public and private sectors and academia. The national debate and the exchange with foreign experts ultimately culminated in the identification of three overall guiding principles that guide the implementation of a carbon price: budget neutrality, long-term orientation, and concomitant implementation of complementary policies (Belgian Federal Climate Change Section et al., 2018[41]).

Support for implementing carbon pricing instruments is already provided by a number of countries, sub-national governments and multilateral initiatives. For example, the European Union established bilateral partnerships with China and South Korea, providing technical assistance, that draws from own experience, for the launch of the Chinese and Korean emission trading schemes. Similarly, the Canadian Province of Québec signed a Memorandum of Understanding with Mexico, in which Québec seeks to share its carbon market experience (Québec government, 2018[42]). The World Bank's Partnership for Market Readiness (PMR) assists countries by consulting on the choice of the pricing instrument most suitable for the country-specific circumstances and by improving on the technical and institutional readiness. As of 2017, 19 countries are readiness participants, including many Latin American, African and East-Asian economies (Partnership for Market Readiness, 2017[43]). In addition, the PMR generates and disseminates knowledge on carbon pricing instruments drawn from the experience of contributing countries.

Sharing experiences and exchanging best-practices facilitate the design and implementation of innovative and more effective pricing instruments. A diversity of pricing initiatives with different designs in different jurisdictions provides opportunities for experimenting, learning, and innovating. There is no one size fits all approach with respect to carbon pricing; tailoring pricing instruments to the country-specific circumstances is key for the effectiveness and acceptability. Exchanging best-practises and sharing experiences enables countries to improve on the effectiveness of existing instruments and to adopt instruments that have proven most effective. However, a large diversity of pricing schemes may also create barriers to deeper international co-ordination in the long-run when design features are incompatible with each other.

4.2. Facilitate the implementation of internal carbon prices

New carbon pricing instruments such as internal carbon prices for the evaluation of public projects can broaden the economic coverage of carbon pricing by including the public sector, thereby complementing carbon prices that apply for the private sector. Adopting an internal carbon price for the evaluation of public investment projects by ex-ante cost-benefit analysis (CBA) is best practice and has many benefits, notably ensuring the cost of climate change is taken into account within public investments (OECD, 2018[44]). This practice can have large impacts as government's expenditure for providing public goods amounts to between 5% and 11% of GDP across OECD countries (OECD, 2019[45]). Internal carbon prices align the incentives of the governments with climate goals when procuring public projects.

Internal carbon prices in CBA is used increasingly in recent years, but price levels are too low. A number of OECD countries use CBAs when assessing public investment projects in two emission-intensive sectors: transport and energy (OECD, 2018[44]). However, the applied carbon values are often lower than EUR 40, the lower end of the price range to be consistent with the Paris Agreement. The European Commission sets CBA guidelines for projects with an investment volume larger than EUR 50 million, requiring co-financing from the EU (European Commission, 2015[46]). The CBA guidelines require the evaluation of both direct emissions (e.g. emissions caused by the construction and operation) and indirect emissions (e.g. emissions caused by increased demand for energy and any additional supporting activity or infrastructure). The unit costs in the EU appraisal methodologies vary depending on the project between EUR 10 and EUR 40, but are increasing over time, reflecting rising social costs of carbon.

Government's budget and fiscal policy is one of the most important tools for policy makers to streamline environmental goals, including climate change mitigation, into their national policies. The Paris Collaborative on Green Budgeting aims at designing new, innovative tools that improve the alignment of national expenditure and revenue processes with climate and other environmental goals (OECD, 2018[47]). By incorporating environmental dimensions into fiscal frameworks, including the annual budget document and evaluation of tax and expenditure policies, these frameworks are better aligned with pathway that are consistent with the goals of the Paris Agreement and the UN Sustainable Development Goals.

Sharing best-practice approaches, encouraging other governments to make use of internal carbon pricing in CBAs, and co-ordination on the price level may facilitate wider application of internal carbon prices while increasing their effectiveness. Including GHG emissions into CBAs for public projects is a rather recent development and is still subject to certain implementation barriers, including methodologies on how to estimate project-based direct and indirect emissions or how to determine the unit cost of carbon (most countries base their unit cost on an estimation of a country-specific social cost of carbon). Guidelines and best practise examples on these dimensions can overcome the barriers and facilitate the application of internal carbon prices in CBAs. In addition, these guidelines and best practise examples could be also adopted by private entities that are willing to apply internal carbon prices for their investment projects.[7]

4.3. Phasing out inefficient fossil fuel subsidies

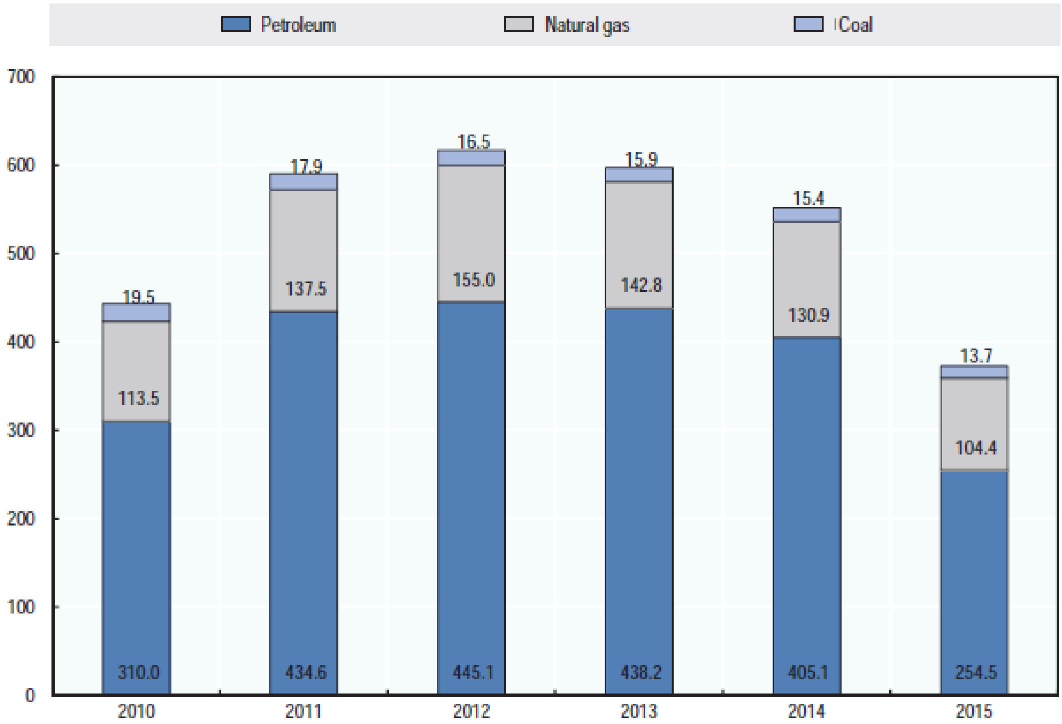
Support for fossil fuels, through direct transfers to consumers and producers or preferential tax treatments, sends the wrong price signal to emitters and encourages the consumption of fossil fuels (OECD, 2015[48]). Fossil fuel subsidies (FFS) result in artificially low energy prices, which reduce the effective carbon rates and lock-in emission-intensive modes of consumption and production, while hampering the transition to a low-carbon economy. They can aggravate local air pollution and represent a considerable strain on public budgets, lowering scarce fiscal resources that could be used more efficiently elsewhere. Moreover, the social goals that FFS intend to support, can be achieved more cost-effectively by other means (Rentschler and Bazilian, 2017[49]).

Support for fossil fuel is still substantial, but has been declining ultimately. Annual support of fossil fuels is estimated to range between USD 370 billion and USD 620 billion over the period 2010 to 2015, based on data from 76 economies, covering 94% of global CO_2 emissions (Figure 4.2). While annual support has peaked in 2012, it has been declining to reach its lowest point in 2015. This decline was due to policy reforms, but primarily due to a fall of the international oil price as the support for the consumption of petroleum products represents the bulk of the overall figure, accounting for more than two thirds of the total support figure in each year. A decomposition analysis for the government support provided through the under-pricing of fossil fuels shows that 60% of the drop in support between 2014 and 2016 is due to the decline of the international oil price. The rest of the change can be attributed to domestic price reforms as well as other factors, including exchange rates, domestic fuel consumption, transport and distribution costs.

The relative magnitude of support for fossil fuels is considerable, making it a major field for policy reforms. First, fossil fuel support is multiple times higher than the value of all currently existing carbon pricing schemes combined (USD 82 billion in 2018 according to (World Bank and Ecofys, 2018[5]). Second, the share of FFS on economic activity measured by gross domestic product (GDP) averages 0.23% for the above sample, but can be well above 1% in some countries.

[7] Over 1300 firms are already using or are planning to use an internal carbon price in 2018 with the internal corporate carbon price varying between USD 0.01 and 909 per ton CO_2e across all companies (World Bank and Ecofys, 2018[5]).

Figure 4.2. IEA-OECD joint estimate of support for fossil fuels



Source: (OECD, 2018[50]).

Several countries have undertaken major fuel pricing reforms. Mexico introduced a floating excise tax that aims at eliminating the support of diesel and gasoline consumption (Arlinghaus and van Dender, 2017[51]). Indonesia completely phased out its gasoline subsidies in 2015 and capped the support of diesel consumption with the cap decreasing over time. While FFS represented 30% of government expenditure in 2012, this figure dropped to 6% in 2017 (OECD, 2018[50]). After having started the reform in 2010, India successfully deregulated gasoline and diesel prices in 2014. Several countries reformed their energy taxation systems. While Sweden phased out the reduction of the CO_2 tax rate for energy-intensive firms and the agricultural sector, France removed the excise tax exemption for fuels used in combined heat and power (CHP) generation in 2017. Tax exemptions with respect to heating fuels have been removed in Estonia, Finland, and the Canadian province of Newfoundland and Labrador.

Reforming fossil fuel support can bring multiple benefits, but also faces strong barriers hindering the reform process. Reforms can enhance a countries' policy coherence with respect to its climate objectives, free up fiscal resources and being non-regressive as richer households tend to benefit more from existing fossil fuel support. However, some barriers – particularly related to the impact of reforms on energy poverty of poor households and on the competitiveness of domestic firms – exist, but can be addressed by complementary and more effective policies. These barriers are responsible for rendering fossil fuel prices a sensitive policy area for governments while challenging the political acceptability of fossil fuel reforms.

International co-ordination can help governments to overcome some of the barriers and create momentum in the reform process. International co-ordination on phasing out inefficient FFS has gained momentum, starting in 2009 when G20 leaders agreed to 'rationalise and phase-out inefficient fossil fuel subsidies that encourage wasteful consumption over the medium term' (G-20, 2009[52]). Member economies of the Asia-Pacific Economic Cooperation (APEC) made a similar pledge (APEC, 2009[53]). In 2010, the Friends of Fossil-Fuel Subsidy Reform initiative has brought together like-minded countries beyond G-20 and APEC to advocate reform (Government of New Zealand, 2018[54]). The reform progress has gained new momentum in 2016 when G7 leaders added a firm timeline by committing to eliminate inefficient FFS by 2025 (G7, 2016[55]).

Both APEC and G20 leaders agreed to reciprocal peer reviews of their national fossil fuel support (OECD, 2015[48]). Several countries (e.g. China, Germany, Mexico, and United States) completed the peer reviews, while peer reviews are currently ongoing in Indonesia, Italy, and Viet Nam and will shortly begin in Argentina and Canada. The reviews benefit both the reviewed and the reviewing countries by enhancing transparency, providing the opportunity to examine current policies and identify the most effective reform areas.

4.4. Sectoral approaches to carbon pricing

Sectoral approaches are seen as a means to mitigate sector-specific GHG emissions while addressing concerns on competitiveness and on economic growth (Meunier and Ponssard, 2012[56]). A sectoral approach stipulates that there are joint binding rules to mitigate GHG emissions for that sector, though these rules may differ across countries and sectors.

Sectoral approaches to co-ordinate on carbon pricing can involve many benefits that may allow for deep emission reductions. These benefits include:

- Addressing competiveness concerns, particularly for energy-intensive trade-exposed (EITE) sectors (e.g. aluminium, cement, steel). These sectors frequently express concerns about the competitive and distributional impacts of asymmetric carbon prices across countries (Worldsteel, 2017[57]). Internationally co-ordinated carbon prices would help these sectors to mitigate emissions cost-effectively while facilitating fair competition of firms in different jurisdictions. Fair competition can allow governments to scale down or remove complementary measures addressing carbon leakage, including allocating free emission certificates and applying preferential tax rates for firms. This can increase the fiscal space of governments and may improve the environmental effectiveness of carbon pricing, as some of these complementary measures tend to limit the effect on carbon emissions reductions (Dechezleprêtre, Nachtigall and Venmans, 2018[58]).
- Focusing the implementation of carbon pricing instruments on a specific sector reduces the number of stakeholders affected by the pricing scheme and that would need to be consulted. This may facilitate agreement and may result in higher ambition and broader geographical participation, including by countries without pre-existing carbon pricing schemes (Schmidt et al., 2008[59]).
- Simulations have shown that sectoral approaches have the potential to effectively reduce GHG emissions while involving only a low welfare cost as simulations for the cement sector suggest (WBCSD, 2012[60]).[8]

[8] These simulations were based on the assumptions that Annex I countries apply a sector-specific cap-and-trade system whereas non-Annex I countries implement emissions intensity targets with

- Sectoral approaches are also suitable for sectors that do not experience international competitiveness concerns, but where assigning emissions to national boundaries is complicated. These sectors include international maritime transport and international aviation (see below).

Disadvantages of sectoral approaches include the tensions with GHG reduction targets, i.e. how to account for the impact of sectoral approaches in some sectors without reducing the ambition in other sectors given a fixed economy-wide target (Baron et al., 2007[61]). Moreover, sectoral approaches are not necessarily cost-effective as they may result in different levels of carbon prices across economic sectors, leading to different levels of marginal abatement costs.

Sectoral approaches may be implemented by an agreement across national governments or by an industry initiative without the involvement of national governments. Industries can have an interest in setting up these voluntary agreements if they anticipate a set of harsher domestic or international policies that are perceived as having a more negative impact on the profits of firms in the specific industry (Morgenstern and Pizer, 2007[62]). In addition, some firms in developed countries can have an interest in achieving broad sectoral agreements to reduce competition against environmentally badly-performing foreign firms that operate in the same sector and that incur lower compliance costs due to laxer environmental regulation abroad.

In recent years, several low-carbon initiatives from energy-intensive trade-exposed sectors have emerged. For example, the global association of major steel producers (worldsteel) has established sector-wide standards of MRV, collects and distributes data on best-practice approaches for reducing emissions, and coordinates research in low-carbon breakthrough technologies (Worldsteel, 2017[57]). Similar measures are undertaken in the cement sector and in the aluminium sector, two sectors considered to be appropriate candidates for international sectoral approaches (Baron et al., 2007[61]).

At the UNFCCC level, sectoral approaches regarding emissions from international aviation and international maritime transport have gained momentum recently. Both sectors are currently not covered by the Paris Agreement, despite the high emission levels and recent emission growth trends: Emissions from international aviation grew by 105 percent between 1990 and 2015, reaching 529 Mt CO2 in 2015, accounting for nearly 2 percent of global GHG emissions (IEA, 2017[63]). Since technological or organisational breakthroughs, that would allow for substantial emission reductions, are not in sight in the near future, this growth trend is expected to continue with annual growth rates of 5 % (ITF, 2017[64]). While emissions from domestic aviation are currently covered by the EU ETS, the Korean ETS, and the Chinese pilot ETSs Shanghai, Guangdong, and Fujian (ICAP, 2018[18]), the EC postponed the decision about covering emissions from international aviation to support the development of a global measure by the International Civil Aviation Organization (ICAO).

In October 2016, the ICAO agreed on a market-based measure, called Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), being effective as of 2021.[9]

credits and sanctions. Competitiveness concerns due to the asymmetric regulation are addressed by allocating free allowances or introducing border carbon adjustments.

[9] CORSIA is expected to start in 2021 with a three-year pilot phase followed by a second three-year phase. In these six years, only operators flying routes between volunteering States will be required to offset emissions. Starting in 2027, participation in CORSIA becomes mandatory except for small

ICAO aims at stabilising emissions at 2020 levels by requiring airline operators to offset the growth of emissions after 2020. Airlines may offset emissions by purchasing emission units generated by emission reductions in other sectors. Given the predicted emissions trend, the demand for offsets is estimated to be between 443 and 596 Mt CO_2 in 2035, turning the aviation sector to be one of the largest buyers of carbon offsets (ICAO, 2016[65]).

Eligibility criteria for offsets that international operators can use towards meeting the emissions reductions obligation under CORSIA are crucial for safeguarding environmental integrity. Given the projected demand for international offsets from the international aviation sector, robust accounting standards and quality standards for offsets eligible under CORSIA are crucial to offset effectively GHG emissions from international aviation. It remains to be seen in the coming months, which criteria Member States of ICAO will agree on, in particular after Parties failed to deliver rules regarding international emissions trading at COP24, deferring this item for further work in 2019 (IETA, 2018[66]).

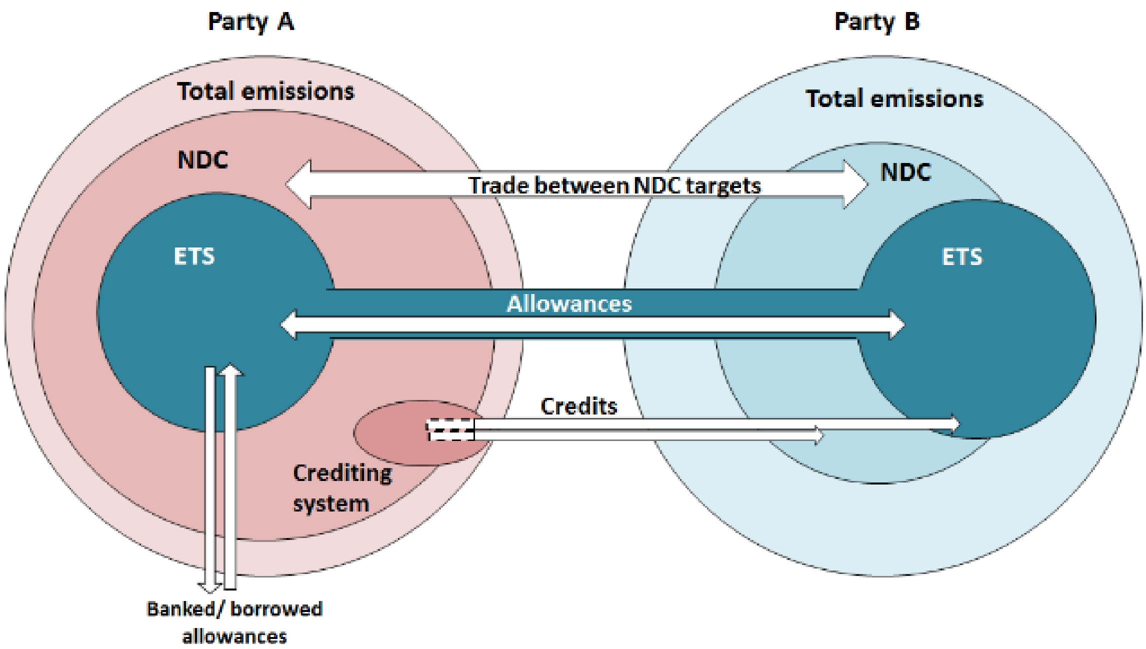
In April 2018, Member States of the International Maritime Organization (IMO) agreed to reduce the carbon emissions of global shipping by at least 50% in 2050 compared with 2008 (IMO, 2018[67]). It remains to be seen which policy instruments will finally be implemented by the IMO, but the recent agreement has opened a window of opportunity to consider the use of carbon pricing as an instrument to encourage the adaptation of low-cost abatement technologies and to decarbonize the maritime sector in a cost-effective way (ITF, 2018[68]).

4.5. International emissions trading and climate crediting mechanisms

International emissions trading can reduce the abatement costs of emitters and countries and transfer financial means for mitigation action to low-cost countries and low cost sectors. This can reduce the overall mitigation costs and can lead to enhanced mitigation ambition in the future. Figure 4.3 provides a schematic overview of different flows of mitigation outcomes flowing between NDC boundaries. These trading flows could include credits or offsets, trade between NDC targets, emission allowances and banked/borrowed allowances. Banking and borrowing, if permitted, would allow for intertemporal transfers of allowances. Trading emission allowances between emission trading schemes is discussed in Section 4.6. This Section deals with the trade between NDC targets and crediting mechanisms.

island States, least developed countries and land-locked developing countries with less than 0.5% air traffic.

Figure 4.3. Potential flows of mitigation outcomes flowing between NDC boundaries



Source: (OECD and IEA, 2016[69]) adapted from (Prag, Briner and Hood, 2012[70]).

4.5.1. Climate crediting mechanisms

Climate crediting mechanisms reduce the abatement cost for emitters and transfer financial means for climate actions to sectors outside the carbon pricing schemes. Crediting mechanisms or offsets enable entities with high abatement costs to purchase low-cost carbon credits from emission reduction projects that can be used towards meeting the emission reduction obligations. This reduces the mitigation costs of jurisdictions or sectors with high abatement costs while providing finance for low-carbon projects in sectors or countries that have large low-cost abatement potential (Burniaux et al., 2009[71]).

Crediting mechanisms, such as the CDM, enable ETSs to link indirectly. The CDM – one of the flexibility mechanism under the Kyoto Protocol – allows Annex I countries[10] to meet part of their emission reduction obligations in non-Annex I countries. Many ETSs (e.g. New Zealand, Tokyo, EU ETS) established one-way links to the CDM by allowing regulated entities to use CDM credits towards meeting their emission reduction obligation. When multiple ETSs link to the same offset scheme, they form an indirect link which can lead to some convergence of the permit prices between the ETSs. In this case, offset credits would establish a common currency across multiple ETS.

The CDM has resulted in savings of mitigation costs and has been the largest offset market. As of 2018, more than 7,500 CDM projects generating almost 2 billion certified emission reduction units (CERs) have been realised (UNFCCC, 2018[72]). The EU ETS was the major buyer of CERs benefiting from low-cost abatement options: Estimates suggest that between 2008 and 2009 EU ETS entities saved at least 280 million Euro by purchasing CERs instead

[10] Annex I Parties include 43 industrialised countries and economies in transition.

of realising higher-cost domestic emissions reductions (Trotignon, 2012[73]). The price of CERs has been oscillating around EUR 20 in the years before the global financial crisis and dropped under EUR 1 as of 2012, primarily because of limited demand from the EU ETS, the major buyer of CERs, and increasing uncertainty about the future of CDM credits (Newell, Pizer and Raimi, 2013[74]).[11] However, the oversupply of CDM credits and the resulting price decline was anticipated (Baron, Buchner and Ellis, 2009[75]).

Offsets have triggered several discussions around environmental integrity, particularly questioning the additionality of projects (Schneider, 2009[76]). A project is considered additional and should be awarded CERs only if it would not have happened in the absence of the offset (World Bank, 2016[77]). This requires estimating baseline emissions against which actual emissions can be measured to determine the number of CERs the project receives.

In some cases, estimating baseline emissions was subject to fraud. For example, CDM credits for the destruction of hydrofluorocarbons appears to have triggered perverse incentives to build additional refrigerant-producing factories solely for the purpose of destroying their HFC-23 emissions. For this reason, the EU ETS ceased to accept CDM credits from the destruction of HFC-23 (Schneider, 2011[78]).

4.5.2. International emissions trading under Article 6 of the Paris Agreement

Article 6 of the Paris Agreement outlines different approaches to international co-ordination amongst Parties "to allow for higher ambition in their mitigation and adaptation actions" (UNFCCC, 2015[79]). Article 6 will have a significant impact on the future of offset trading and international emissions trading, but the concrete rules still need to be finalised. While Article 6.2 describes internationally transferred mitigation outcomes (ITMOs), Article 6.4 highlights internationally supervised mechanisms. Parties could not agree on the rule book of the Paris Agreement related to Article 6 at COP24 in 2018, but deferred this item to 2019. There are still many open questions, including:

- Environmental integrity and avoidance of double counting. Environmental integrity in the context of international emissions trading implies that co-operative approaches do not result in higher global emissions relative to the absence of emission trading. Robust accounting standards need to be established to ensure that emission reductions are counted and claimed only once: either for the host country's NDC or for the offset market. Rules and guidelines need to be established to account for trading mechanisms that are currently outside the Paris Agreement such as CORSIA (Hood and Soo, 2017[80]). Other open questions include whether countries without GHG-targets may be eligible to trade GHG reduction units, whether trade of non-GHG units should be feasible (e.g. generation of renewable energy) and how to account for trade between countries that have different types of

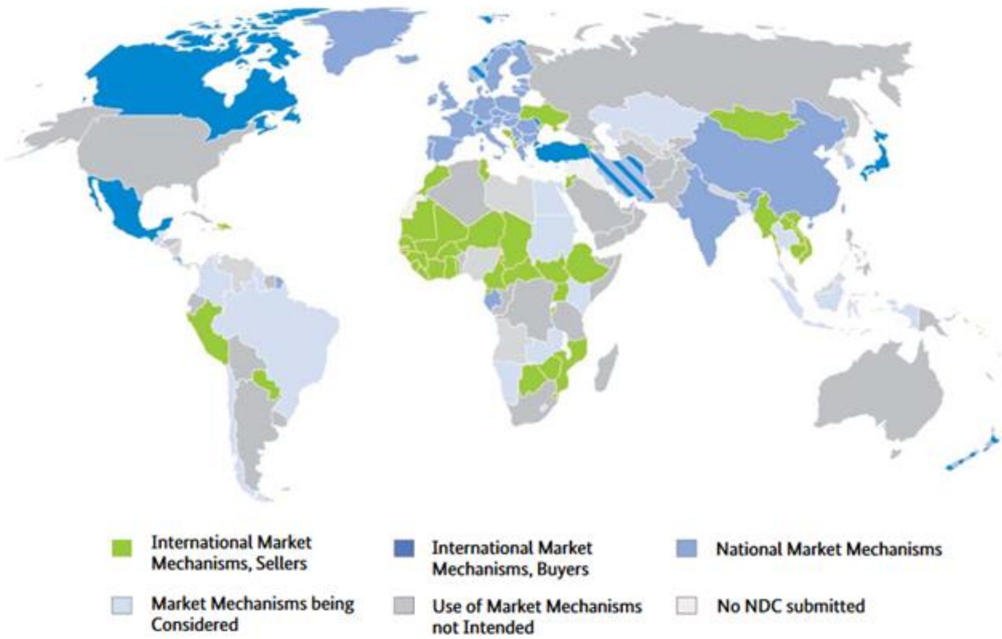
[11] As a response to low CDM prices, the EU ETS limited the purchase of carbon credits to prevent the market price in the EU ETS to fall too much. The RGGI has followed a more dynamic approach by pegging the number of carbon offsets to be used depending on the emission price in the market. For example, if carbon prices reach 7\$/t CO_2e, then emitters are allowed to purchase more offsets to meet their compliance needs than is otherwise allowed. If carbon prices are above 10\$/t CO_2e, emitters may purchase even more offsets. By doing this, the offset market effectively smooths the carbon price in the RGGI, thereby reducing volatility and preventing price spikes. However, this mechanism is clearly less transparent than an explicit price ceiling at which allowances can be purchased from the government.

targets (e.g. single-year versus multi-year target) (Hood and Soo, 2017[80]; Vaidyula and Hood, 2018[81]).

- Quality standards of reduction units. Some countries indicate that stringent eligibility criteria are required to give jurisdictions and investors more confidence that offset markets are underpinned by robust standards (New Zealand, 2015[82]). Eligible projects should comply – at a minimum – with the environmental standards established under the UNFCCC, including adoption of methodologies for baseline estimation and principles for quantifying emission reductions (e.g. transparency and conservativeness). Further multilateral co-ordination on quality aspects could set a higher standard for emission allowances.
- Vintage of reduction units. The question is whether and how existing CDM credits can be transferred to Article 6 of the Paris Agreement and used afterwards. Transferring CDM credits to the Article 6 mechanism may transfer the oversupply of credits to the newly established scheme from the outset and may lead to low price levels. As of November 2018, there are around 430 Mio credits in the holding accounts of the CDM registry (UNFCCC, 2018[83]).
- Additionality. How (and whether) to ensure that emissions reductions from Article 6 mechanisms are additional relative to the reductions that would have happened anyway through the implementation of a country's NDC.
- Baselines. How to calculate baselines for determining the number of awarded credits for emissions reductions. As some developing countries have determined their NDCs relative to a baseline or business as usual scenario, the underlying assumptions and methodologies for determining the baselines are key assess the country's mitigation effort and the global emission reduction (Clapp and Prag, 2012[84]).

While the success of the international trading mechanisms under the Paris Agreement will depend on the concrete rules agreed on at COP24, international emissions trading under the UNFCCC may be limited in scope. The number of countries that announced in their NDCs to sell emissions reduction units on the international markets by far outweighs the number of potential buyer countries (see Figure 4.4), potentially leading to oversupply of ITMOs. However, sectoral approaches such as CORSIA may close the gap between demand and supply for international carbon credits, though the rules and guidelines still need to be finalised.

Figure 4.4. Overview of the use of market-based mitigation instruments in NDCs



Source: (BMUB, 2017[85])

4.6. Co-ordinating on minimum carbon prices

Minimum carbon prices can contribute to convergence of carbon prices across jurisdictions, enabling economic efficiency gains and levelling the playing field while not preventing jurisdictions from imposing higher prices. Minimum prices can be implemented for all pricing instruments: carbon taxes, ETSs, and excise taxes on energy products. While a minimum price guarantees that all co-operating countries charge the same minimum amount for each ton of CO_2 emitted, it gives countries sufficient leeway to align their domestic energy pricing strategy with country-specific circumstances, e.g. addressing other non-climate externalities or raising revenue for financing infrastructure.

The benefits of co-ordinated minimum prices depend on the sector concerned. While the benefits in terms of levelling the playing field may be high in some sectors, including EITE sectors, they might be lower in other sectors such as transport and residential and commercial housing. Still, co-ordinating carbon prices in these other sectors has political value as it sends a political signal, demonstrating commitment to climate policy.

Co-ordinating on minimum excise taxes on energy products such as coal, diesel, gasoline, and oil may have a large impact on price convergence of effective carbon rates. Energy taxes on fossil fuels are already in place in most developed and many developing countries and constitute the major part of effective carbon tax rates on energy use in most sectors (e.g. 99% in road transport, 98% in Agriculture & fisheries, 96% in offroad transport, 93% in residential and commercial) (OECD, 2018[7]).

The European Union established minimum excise duties on mineral oils used as propellants or for heating for its member countries with the Council Directive 92/82/EEC in 1992. In

2003, the EU regulation for energy taxation was revised and extended with Directive 2003/96/EC, which included a stepwise increase of minimum excise duties for gasoil and kerosene. In addition, the new regulation differentiates the minimum tax rates for coal and coke, electricity, and natural gas between business and non-business applications. Table 4.1 provides an overview of the implicit carbon floor prices that result from the EU energy tax rates as of 2017 using the UNFCCC emissions factors. As described in Section 2.3, implicit carbon rates tend to be much higher in the transport sector. In addition, business users face lower tax rates for coal and electricity, but higher ones for gas. The minimum implicit carbon tax rates amount to 140 EUR/t CO_2 for petrol and 7.5 EUR/t CO_2 for gasoil for heating. Even though these tax rates are not aligned with climate mitigation targets and vary substantially across fuels, they constitute a lower bound for effective carbon rates. While the excise duties in some countries exactly correspond to the minimum levels of the EU, they are considerably higher in other countries. For example, the implicit carbon rate for petrol in the Netherlands, the country with the highest tax on petrol, amounts to 300.93 EUR/t CO_2e, which is more than double the minimum excise duty.

Table 4.1. Implicit carbon rates due to minimum excise duties in the EU

Taxed energy product	Tax rate in EUR/t CO_2e
Petrol (motor fuel)	140.32
Gas oil (motor fuel)	117.68
Gas (motor fuel)	48.15
Coal for heating - business use	1.60
Coal for heating – non-business use	3.19
Gas for heating – business use	21.30
Gas for heating – non-business use	5.56
Gasoil for heating – business use	7.49
Gasoil for heating – non-business use	7.49

Source: Directive 2003/96/EC, Annex I; (IPCC, 2006[86]) guidelines

Co-ordinating on carbon price floors for explicit carbon pricing instruments is a promising means to strengthen the price signal and to address price fluctuations, but requires that carbon pricing instruments are either already in place or that are expected to be implemented in all participating jurisdictions. A less volatile carbon price may increase certainty for investments and research in low-carbon technologies (Edenhofer et al., 2017[87]). Jurisdictions may not be obliged to implement the same policy instruments, but may choose the pricing instrument that is most appropriate for their specific circumstances. Canada followed this approach when implementing the Pan-Canadian Framework on Clean Growth and Climate Change (Box 4.1). This gives jurisdictions enough regulatory leeway for the design of the pricing instrument while ensuring that all parties are facing the same minimum price.

Several ETSs have implemented carbon price floors. For example, the ETSs in California, Quebec and Regional Greenhouse Gas Initiative (RGGI) are operating with a price floor (ICAP, 2018[18]). In each of these programs the price floor has been binding in at least one auction and the price has subsequently risen above the floor (Hepburn et al., 2016[88]).

In the EU, the United Kingdom unilaterally introduced a carbon floor price for the power sector in April 2013 starting at 9 GBP/t CO_2e. While the floor price was planned to reach 30 GBP/t CO_2e by 2020 it is currently frozen at 18 GBP/t CO_2e as reaction to the low permit prices in the EU ETS that would put energy-intensive trade-exposed firms in the UK at a competitive disadvantage relative to their European competitors (Hirst and Keep, 2018[21]).

Technically, the carbon price floor is implemented by the Carbon Support Price, which tops up the EU ETS permit price to reach the target floor price for electricity generators. The UK carbon floor price is associated with a substantial decline in coal consumption for power generation due to the closure of many coal power plants (Figure 4.5), resulting in deep emission reductions (Newbery, Reiner and Ritz, 2018[89]). The decline in the demand for EU ETS permits from UK electricity generators may have aggravated the low level of the permit price in the EU ETS.

Figure 4.5. Coal use before and after the implementation of the UK Carbon Floor Price

AMOUNT OF COAL USED IN ELECTRICITY GENERATION.

Note: UK Carbon Price Floor was introduced in April 2013, indicated by the red line.
Source: (Hirst and Keep, 2018[21])

Box 4.1. The Pan-Canadian Framework on Clean Growth and Climate Change (PCF)

The PCF includes carbon pollution pricing as a central element. The pan-Canadian approach to pricing carbon pollution establishes a federal benchmark to ensure pricing is in place in all jurisdictions in Canada (Environment and Climate Change Canada, 2016[14]). The benchmark provides provinces and territories the flexibility to implement their own system – either an explicit price-based program or cap-and-trade – or have a federal system applied. The benchmark sets common principles and criteria, including that pollution pricing be applied to a common and broad set of emission sources with increasing stringency over time, to minimize interprovincial competiveness impacts.

The federal benchmark includes a minimum carbon price of 10 Canadian Dollars (CAD) per tonne in 2018, and rises by 10 CAD each year until reaching 50 CAD in 2022. This is the minimum price for provinces that choose an explicit price-based system. For provinces with cap-and-trade, the annual caps must be set such as to equal at least the projected emissions resulting from the minimum carbon price that year.

The federal government will introduce a federal carbon pollution pricing system, in whole or in part, as a backstop in provinces or territories that request it, or do not have a system in place that meets the benchmark. The federal system includes a fuel charge on fossil fuels and an output-based pricing system with emissions trading for industrial facilities emitting 50 kt CO_2e or more per year (with the ability for smaller facilities to opt in). The carbon pricing revenues, including those of the federal backstop, will remain in the province of origin.

4.7. Direct linking between carbon markets and other price instruments

A direct link between emission trading schemes can maximise efficiency gains due to full price convergence across linked markets. A single carbon price in the linked system harmonises marginal abatement costs, implying that participants meet the joint emission reduction target at the lowest economic cost while eliminating competitive distortions related to carbon price differentials among the linked economies.

4.7.1. Forms of linkages

There are multiple forms of direct linkages: Unilateral, bi-lateral, and multilateral.

- Under *unilateral linkages* entities under a system A can use and purchase permits form a system B, but not vice versa. For example, Norway accepted allowances from the EU ETS in Phase I, but the EU ETS entities could not use Norwegian permits for compliance. Unilateral linking leads to price convergence if the permit price of the system, which establishes the unilateral link, exceeds the price of the other system. In this case, emitters in the linking jurisdiction will demand allowances from the linked system, thereby raising the price there (and lowering the price in the own scheme), until the permit prices are equal in both systems. Otherwise, there is no incentive for inter-system trading. If a large system links to a rather small one, then the price of the small system could increase significantly if the link causes a large withdrawal of allowances. In this case, the regulator of the small scheme may restrict carbon trading to domestic entities only, thereby limiting the risk of losing control over its own scheme and guaranteeing that emissions are reduced domestically (Mehling and Haites, 2009[90]). Contrariwise, if a small scheme establishes a unilateral link to a large one, then the impact on the permit price of the large scheme is rather negligible. In fact, in this case unilateral linking de facto can be seen as a price floor for the smaller system (Tuerk et al., 2009[91]).

- Bilateral linking allows entities in both jurisdictions to use allowances of the other system. Examples for bilateral linkages include the link between the Californian ETS and Quebec, as well as the planned link between the EU ETS and Switzerland. Without restrictions, e.g. in form of import quotas, direct bilateral linkage leads to full price convergence across the linked jurisdictions.
- If more than two jurisdictions participate in a linked market, this becomes a multilateral link. For example, Ontario joined the California – Quebec ETS in 2018, providing the first real-world example of a multilateral link. However, in July 2018, Ontario's premier elect Doug Ford revoked the joined cap-and-trade scheme (ICAP, 2018[92]) Multilateral links require a higher degree of coordination on the key design features. Much will depend on how the multilateral link evolves, i.e. whether there will be a common governance framework or whether the multilateral link evolves organically through incremental expansion of existing bilateral linkages without central co-ordination (Mehling and Görlach, 2016[93]).

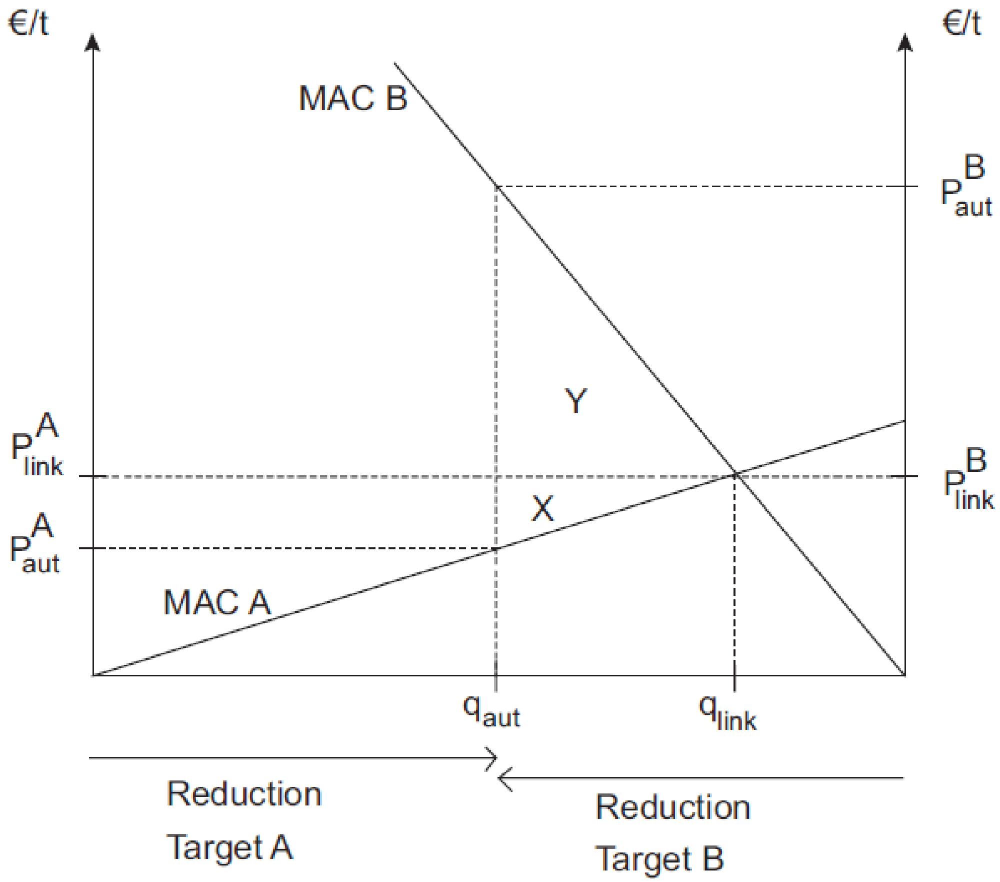
A link between an ETS and a carbon tax would be – in theory - also feasible. In this case, the two systems can be linked by allowing ETS permits to be remitted as payment for the tax and by allowing payment of taxes in excess of the emissions in the country with the carbon tax to earn carbon credits that can be sold in the other jurisdiction (Metcalf and Weisbach, 2012[94]). Essentially, one can think of the tax of being a permit system with a fixed price. However, it is hard to imagine that unrestricted linkage between a tax and an ETS is politically feasible because it would turn the ETS essentially into carbon tax. Instead, quantitative limits on the flow of units across both systems are likely to be the most suited design options, leading to partial convergence of prices.

4.7.2. Benefits from linking carbon markets

Direct linking of ETSs brings many benefits for the parties involved (ICAP, 2016[95]): economic benefits in terms of saving mitigation costs, benefits derived from a larger size of the carbon market and political benefits in terms of creating an institutional 'lock-in'

- Linking carbon markets results in savings of abatement costs and leads to full convergence of the permit price across jurisdictions. Figure 4.6 illustrates the basic mechanism: The carbon prices before linking in the regions A and B were P_{aut}^{A} and P_{aut}^{B} while both regions complied with their emission reduction target, incurring abatement costs equal to the area under the curves *MAC A* and *MAC B* respectively. After linking the joint carbon price in both markets is $P_{link}^{A} = P_{link}^{B}$. Region B becomes a permit buyer because the joint carbon price is lower than the marginal abatement costs between q_{aut} and q_{link}. In total, region B saves abatement costs equal to the area *Y*. Region A increases its (low-cost) abatement and sells the additional permits to region B. The welfare gain of region A equals *X*, which is the difference between the financial transfers from region B to region A (the joint permit price P_{link}^{A} times the traded quantity $q_{link} - q_{aut}$) less the additional abatement costs, i.e. the area below *MAC A* between q_{aut} and q_{link}. The welfare gain of the region with the steeper marginal abatement cost curve (region B) is larger than the gain of the other region, indicating that the gains from trade may be distributed unequally across linked partners. The financial transfers flowing from region B to region A equal the area $P^A_{link} * (q_{link} - q_{aut})$.

Figure 4.6. Benefits from linking and associated financial flows.



Note: MAC refers to marginal abatement cost curve.
Source: (Flachsland, Marschinski and Edenhofer, 2009[31])

- Linking carbon markets yields additional benefits associated with a larger size of the carbon market. A larger carbon market increases the liquidity, thereby guaranteeing the proper functioning of the market. Linking carbon markets increases the number of entities covered, which also reduces the market power in the permit market that some actors might have had before linking. Linkage between markets is also able to absorb asymmetric shocks, thereby increasing price stability. This reduces the risk of the private sector to invest in low-carbon technologies and increases the finance towards climate mitigation. However, greater openness of a linked trading system also implies a higher exposure to external market shocks.
- Linked schemes can create an institutional lock-in in the sense that they might be less sensitive to the lure of discretionary policy than schemes in autarky, due to mutual pressure among linking partners not to relax emission caps. For example, the rules of the sub-nationally linked ETS of the Western Climate Initiative request

a year's notice for any jurisdiction wishing to leave the joint carbon market. Pulling out without appropriate notice may lead to lawsuits and high costs for the parting jurisdiction (Buchanan, 2018[96]). At the same time, national policy makers can point to the pressure of linked partners when justifying the domestic caps against national stakeholders, claiming that the pressure from other countries to a certain extent 'ties their hands' (Flachsland, Marschinski and Edenhofer, 2009[31]).

4.7.3. Barriers to linking carbon markets

Some key design principles and design elements of carbon markets represent significant barriers for linkage (Ellis and Tirpak, 2006[97]). Hence, prior to linking carbon markets, jurisdictions need to agree on key design principles, including the relative stringency of targets, the stringency of enforcement, and the eligibility of offset credits and cost-containment measures.

- The relative stringency of the cap represents a major barrier to linking carbon markets. This refers to the 'hot air' argument according to which low abatement cost countries in an internationally linked carbon market have an incentive to expand their cap, thereby generating higher revenues from selling more permits to the linked jurisdiction (Helm, 2003[98]).[12] This issue arises when jurisdictions in a linked carbon market can set their caps individually.[13] For example, under the EU ETS the member states of the EU submitted their caps to the European Commission (EC) in the first two trading phases. The EC as a central instance evaluated these caps and asked some countries to revise their caps and to resubmit more ambitious targets. In the third trading phase (2013 – 2020), the setting of the cap was delegated to the EC, which finally solved the problem of hot air.
- Large differences in the structure of the marginal abatement costs and differences in the desired price range can prevent linkage in the first place. In this case, the gains from linking are substantial, but are also associated with political challenges. If both carbon markets are similar in size, then linkage would potentially imply large financial flows from the high abatement cost country to the low abatement cost country (see Figure 4.6). While the high abatement country may lack political support for the link due to the financial transfers involved, the low abatement cost country would face a rather high permit price, which may be opposed by some domestic lobby groups. Thus, linkages may be more likely between jurisdictions that have relatively comparable marginal abatement cost curves and show relatively similar ambition, both of which would translate into carbon prices of the same

[12] The incentive for some jurisdictions to increase their cap in a linked scheme can, under some conditions, even lead to higher aggregate emissions relative to the case in which jurisdictions operate their ETSs in autarky (Weitzman and Holtsmark, 2018[135]).

[13] Since cap levels in combination with the regional abatement cost structure determine the international distribution of mitigation costs (see Figure 4.6), jurisdictions implicitly consider their levels of effort as mutually acceptable when linking their carbon markets. Although the Paris Agreement establishes an internationally accepted burden-sharing rule among all participants, this may not necessarily translate into ETSs having a comparable relative stringency. In fact, the caps of ETSs may be more or less stringent than the national target because ETSs typically do not necessarily cover all emissions mentioned in the NDCs and theoretically may even cover areas not mentioned in the NDC.

magnitude pre-linkage. This creates a climate policy paradox to the extent that the linkages with the largest potential of reducing mitigation costs may not be politically feasible. Conversely, politically feasible linkages may yield only modest cost-effectiveness benefits (Ranson and Stavins, 2016[99]). This questions the role of linkages as a means to harmonize permit prices across jurisdictions since the benefits are likely to be rather modest while the drawbacks, e.g. in terms of losing regulatory control might be considerable.

- Countries may lose regulatory control as some design features may spill-over from one system to the other, requiring co-ordination before the ETSs link (Prag, Briner and Hood, 2012[70]). These measures include the provision of offsets, borrowing provisions, as well as cost containment measures such as floor prices and price ceilings. When these provisions are applied by one of the linked systems, they become automatically available for participants of the other scheme, although this scheme does not provide for these provisions (Jaffe and Stavins, 2008[100]).
- Linking may undermine environmental integrity through various channels: First, linking may raise concerns about (insufficient) domestic emission reductions when regulated entities use foreign certificates for compliance. This is particularly relevant when countries' climate change policies does not only aim at mitigating GHG emissions, but also addresses other environmental problems such as local air pollution. Second, if a partner's ETS is not sufficiently robust, this may undermine the robustness of the whole linked system (ICAP, 2018[101]). Similarly, a linked scheme can become less robust, if some participants have established links with other ETSs or crediting mechanisms with weak environmental integrity. Third, differences in cost-containment measures can lead to higher aggregate emissions in some, but rare cases.14 Fourth, environmental integrity can be also undermined if one of the linked systems allows for excessive borrowing of permits. If future abatement costs are very high, then governments might have an incentive to reduce their ambitions and to relax the cap in future (Boemare and Quirion, 2002[102]).
- Unilateral policy changes may impact the entire linked system through the permit price. For example, the United Kingdom unilaterally introduced a carbon floor price for the power sector in April 2013 starting at 9 GBP/t CO_2e, and currently frozen at 18 GBP/t CO_2e until 2020 as reaction to the low permit prices in the EU ETS (Hirst and Keep, 2018[21]). While the UK carbon floor price is associated with deep emission reductions due to the closure of many coal power plants (Newbery, Reiner and Ritz, 2018[89]), it also exacerbated the low price level of EU ETS permits due to reduced permit demand. Similarly, unilateral non-ETS policies such as support of renewable energy may crowd out domestic electricity generation from fossil power plants, leading to lower than expected permit prices (OECD, 2011[103]). This effect - generally referred to as waterbed effect – stems from the fixed emission cap in the short term that essentially prevents additional climate policies

[14] For example, if one of the linked schemes implemented a price ceiling whereas the other did not, then the price ceiling would automatically apply for both systems. If the permit price of the joint scheme exceeded the ceiling, then companies would only abate until the marginal abatement costs equal the price ceiling. In this case, aggregate abatement would be too low so that actual emissions would exceed the joint cap of the system, thereby undermining the environmental integrity of the combined scheme. Hence, the price ceiling and the penalty of non-compliance (de facto functioning as a price ceiling) should be set high enough to safeguard environmental integrity.

from materialising into emission reductions, but translates into a decline of the permit price (Burtraw et al., 2017[104]).

Co-ordination on the key design elements and policy choices mentioned above can overcome political barriers that may prevent jurisdictions from linking their carbon markets in the first place. As these design elements and policy choices mentioned above represent major barriers for linking carbon markets that prevent jurisdictions from linking and reaping the benefits associated with a linked trading scheme, they need to be harmonised beforehand to make linking feasible (Ranson and Stavins, 2016[99]).

4.8. Carbon market clubs and carbon pricing clubs

Carbon pricing clubs and carbon markets clubs can realize economic benefit for its members and can encourage participation of jurisdictions by adopting complementary measures. These complementary measures include border carbon adjustments (BCAs) (Keohane, Petsonk and Hanafi, 2017[105]) or uniform trade tariffs imposed on non-members (Nordhaus, 2015[106]). Both measures increase the costs of non-membership thereby encouraging participation and addressing the free-rider problem, which is at the heart of international climate negotiations.

4.8.1. Carbon markets club

The major purpose of a carbon market club would consist in providing the infrastructure necessary to link carbon markets across its members and to encourage new jurisdictions to join, thereby increasing ambition over time. Carbon market clubs would support the development and the harmonisation of domestic carbon markets by establishing common standards for the market infrastructure to ensure transparency as well as environmental integrity, providing assistance in capacity building, providing a platform for sharing experience among members, and mutually recognizing member's emission units. A club of carbon markets could serve as a starting point for broadening participation and increasing ambition of club members.

The economic incentives for participation include the benefits of linkage in terms of increased economic efficiency, the use of the existing environmental markets infrastructure, enhanced transparency, exchange of best-practices, and institutional capacity building. Moreover, club members will also enjoy reputational benefits by signalling climate leadership thereby enhancing their international recognition. Club members would agree not to trade emission units with non-member jurisdictions, thereby creating a strong incentive for non-members to join.

Most importantly, the club would provide a safe harbour against potential trade measures on carbon-intensive products such as border carbon adjustment (BCA). To address carbon leakage and to level the playing field, BCAs require importers of carbon intensive goods from jurisdictions with laxer climate policies to pay for the carbon content embodied in the product. If countries are deciding to implement BCAs, jurisdictions with stringent climate policies, i.e. club members, would likely be exempted. In addition, club members would exempt each other from BCAs and the club as such might consider imposing BCAs on non-member jurisdictions, which would serve as a powerful incentive for joining the club. Alternatively, the club may also consider to impose trade tariffs on non-members which would be even more effective in encouraging participation (Nordhaus, 2015[106]). However, the question is whether BCAs are compatible with international treaties, particularly with international trade law under the World Trade Organisation (WTO) (Box 4.2).

Box 4.2. Border carbon adjustment and international trade law

There is much uncertainty about whether border carbon adjustments (BCAs) are compatible with international trade law, in particular with the rules under the World Trade Organization (WTO) (Condon and Ignaciuk, 2013[107]). Some authors argue that BCAs do not necessarily violate the WTO rules (Monjon and Quirion, 2011[108]) , whereas others argue that BCAs are likely to be challenged by WTO members with relatively lax carbon regulation (Hufbauer and Kim, 2009[109]). BCAs are trade measures applied to traded products that aim at correcting for cross-country differences in climate policies, resulting in unequal compliance costs for foreign and domestic producers. The WTO-compatibility of BCAs could rest on the two following arguments:

- Differences in processes and production methods (non-product related PPMs) do not affect the physical characteristics of products (e.g. steel) but create a differentiated environmental impact at the production and processing stages only. If such products are thereby considered as not "like", PPM-related requirements – such as BCAs – could apply. For instance, steel produced domestically using low-carbon technologies would be considered a different product from steel produced in a foreign country using a high-carbon-intensity production method. Applying different levels of tariffs on high-carbon steel, depending on how it is produced, would thus (it would be argued) be discriminating according to product differences rather than among WTO members and thus would not violate the WTO's most favoured nation (MFN) principle. Examples of measures relating to non-product related PPMs in the context of climate-change mitigation include the sustainability standards of biofuels implemented by the EU, Switzerland, and the United States (Moïséi and Steenblik, 2011[110]).
- If products are considered "like", BCAs would breach the WTO's "non-discrimination" principle. However, Article XX of the General Agreement on Tariffs and Trade (GATT) contains a number of agreed exemptions from these requirements. In particular, Article XX(g) allows WTO members to take discriminatory measures for a number of agreed purposes, including the conservation of exhaustible natural resources (Cosbey et al., 2012[111]). Whether climate can be considered an exhaustible resource is an open question. In any case, an Article XX(g) exemption requires BCAs – at a minimum – to take the climate policies of foreign countries into account as well as to warrant foreign producers individual treatment, enabling them to demonstrate their usage of low-carbon production technologies (Helm, Hepburn and Ruta, 2012[112]).

A WTO Dispute Panel could also deem BCAs incompatible with WTO law because of its practical implementation. In particular, the determination of the products' carbon content would likely be a central issue of contention. Since emissions data from foreign producers are typically not available, calculating the carbon content requires setting national benchmarks that mirror the carbon intensity of the industry concerned in each country. These benchmarks might be challenged by the exporting countries. The calculation becomes even more problematic for manufactured goods with many and complex suppliers of components (e.g., automotive vehicles) due to the integration of producers in the global value chains. Estimating the carbon content of any given good of this type would require tracking the entire value chain while determining the carbon content for each primary good depending on the country of origin.

4.8.2. Carbon pricing club

Carbon pricing clubs (Nordhaus, 2015[106]), as carbon market clubs, aim at deep emission reductions from participating countries while encouraging participation of non-club members. Drawing on the findings from the literature on international environmental agreements, stating that international (climate) treaties are either broad, but not deep or deep, but not broad (Barrett, 1994[113]), this proposal attempts to overcome the free-rider problem. The proposal centres on an "international target carbon price", i.e. a minimum domestic carbon price, which all countries agree to implement either by carbon taxes, carbon markets or a hybrid. A key design element is to penalize non-member countries by imposing uniform trade tariffs to increase the benefits of membership as well as the costs of non-membership, thereby fostering participation.

Nordhaus' target carbon price is envisioned to be around USD 25 per ton of CO_2. There will be exemptions for poor countries as they cannot be expected to make the same commitment as developed nations. However, once poor countries reach a certain income threshold, they would be obliged to meet the obligations of club membership.

Having prices rather than quantities as the central organizing principle has multiple advantages. First, they are a simpler instrument for international negotiations. While prices have a single dimension, quantitative emission reduction targets have the dimensionality of the number of countries involved in the negotiations, which complicates the negotiation process (Nordhaus, 2015[106]). Second, negotiating on minimum prices rather than quantities effectively addresses the free-rider problem. By accepting a binding minimum price that applies for all countries, negotiators automatically internalize the mitigation effort of all other countries and are thus willing to accept higher price levels (Weitzman, 2017[114]). Third, carbon prices can be implemented easily through carbon taxes that can be levied upstream at a low administrative cost.

Nordhaus (2015[106]) also discusses the use of border carbon adjustment to address competitiveness concerns and to penalize non-membership, thereby increasing the incentives for participation. However, BCAs are not as effective as uniform percentage tariffs (e.g. in the range of 2%) in penalizing non-members – which is the major purpose of having this instrument in place. However, uniform percentage tariffs are a major departure from current international trade treaties and laws and global economic relations. Hence, current international trade laws would need to integrate some climate amendments that explicitly allow for the envisioned uniform tariffs on non-members. This, in turn, would require that countries acknowledge climate change as a major global threat, justifying the use of trade measures while preventing that this approach is used for other worthy initiatives as well (Nordhaus, 2015[106]).

4.9. Towards a single global carbon price?

A single global carbon price would be - in a first-best world without any other externalities and market failures - the first-best solution as it represents the most cost-effective way to mitigate GHG emissions. Abstracting from other externalities, emissions would be reduced at the locations where abatement costs are lowest while eliminating all competitiveness concerns related to carbon leakage.

Carbon prices may differ between low-income and high-income group in a more realistic setting as argued by the High-Level Commission on Carbon Prices (2017). Since low-income countries provide the majority of low-cost abatement options, the largest part of the mitigation effort would fall into their territories. Preventing the major burden of climate change mitigation be borne by low-income countries would require substantial international financial transfers, which may not be politically feasible. In this case, efficiency and equity cannot be separated anymore and carbon prices would be lower in low-income countries, reflecting the income status of countries and acknowledging more pressing development needs, including poverty eradication. While a low-carbon pathway can be compatible with development and poverty reduction in some areas (e.g. increasing the share of low-carbon energy), there are some trade-offs between climate mitigation and development goals in other areas, justifying more moderate mitigation efforts in the short term until the basic needs are met.

Differing carbon prices between country groups does not mean that low-income countries are exempted from contributing to climate change mitigation. It rather reflects the fact that the principle of ‘common, but differentiated responsibilities’ from the Rio Conference (UNFCCC, 1992[115]) also applies for carbon pricing when accounting for country-specific circumstances. Within a group of countries with comparable income level, carbon prices should be as equal as possible. However, the simple binary differentiation between developed and developing countries may be too rough and could be more granular to allow for higher price coherence across countries.

4.10. Summary

This section outlined different levels of co-ordination on carbon pricing that are available for national and sub-national governments. While these levels are roughly ordered according to the depth of required co-ordination, jurisdictions can co-ordinate simultaneously at different levels, involving different levels of government or across sectors. This simultaneous use of different options by different actors can create a ‘web of carbon pricing schemes’ that can deliver on achieving the NDCs in a more cost-effective way while allowing for deeper co-ordination that may raise countries’ mitigation ambition. Table 4.2 summarizes the potentials and the caveats associated with each of the levels outlined in this section.

Table 4.2. Potentials and challenges of co-ordination mechanisms

Type of co-ordination	Potentials	Challenges
Facilitate creation of new carbon pricing schemes	- Broadens geographical and economic coverage of carbon pricing - Relatively easy to implement	- May create barriers for future co-ordination if initial designs are too diverse
Facilitate the implementation of internal carbon prices	- Aligns incentives of governments with climate goals (internal carbon prices)	- Estimating the social cost of carbon requires a set of assumptions (e.g. discounting, expected climate damages)
Phasing out inefficient fossil-fuel subsidies	- Corrects misaligned carbon pricing - Frees up fiscal resources	- Diverse definitions of key terms ("inefficient" or "subsidy") may hamper reform progress - Reforms need to be designed and timed carefully given political economy issues
Sectoral approaches to carbon pricing	- Addresses competitiveness concerns of sector - Allows potentially for ambitious mitigation targets in the respective sector	- Possibly tensions with economy-wide targets or NDCs
International emissions trading and climate crediting mechanisms	- Transfers financial means to sectors/jurisdictions outside of existing schemes - Reduces abatement costs of emitters	- Requires high quality standards for offsets to safeguard environmental integrity - May lead to low carbon prices in ETS if used extensively
Co-ordinating on minimum carbon prices	- Increases price coherence and cost-effectiveness - Lowers price volatility and increases investment certainty - Does not prevent jurisdictions from imposing higher domestic carbon prices	- Countries may only agree on low price levels
Direct linking between carbon markets and other pricing schemes	- Enhances economic efficiency through full price convergence - Increases market liquidity and reduces market power - Sends a political signal of commitment - Creates instituional lock-in	- Requires a high level of policy co-ordination - May lead to loss of regulatory control - NDC targets may not be achieved if emission transfers are not properly accounted for
Carbon market clubs and carbon pricing clubs	- Encourages club participation by benefits and complementary measures (border carbon adjustment, trade tariffs)	- Complementary measures may not be in line with international trade treaties
Towards a single global carbon price?	- Maximises economic efficiency through full price convergence - Eliminates competitiveness concerns related to carbon leakage	- Would imply a shift of the main burden of mitigation action to developing and emerging markets in the absence of major financial flows

Source: Author.

5. Lessons learnt and roadmap for the future

International co-ordination on carbon pricing between different actors at different levels of government or across economic sectors is already taking place. Country experience shows that governments are using simultaneously different options engaging with different jurisdictions to co-ordinate on carbon pricing. This simultaneous use can create a bottom-up 'web of carbon pricing schemes' that may deliver on the NDCs in a cost-effective way while laying the foundations for strengthening co-ordination and increasing the number of co-operating jurisdictions. This section summarizes the lessons learnt from each of the levels of co-ordination on carbon pricing, outlined in Section 4. It also provides potential next steps for governments on how to advance on the respective level.

5.1. Facilitate the creation of new carbon pricing schemes

In recent years, several multilateral initiatives have emerged to offer a platform for further discussing carbon pricing among private and public stakeholders. These platforms facilitate the exchange of information of carbon pricing experiences, enable to share best-practice approaches, and provide capacity development for countries, willing to implement carbon pricing. This facilitates the implementation of effective carbon pricing in other countries. In addition, these initiatives are discussing the design of common rules and general accounting standards, both of which are crucial elements for enabling deeper co-ordination in the future.

Providing technical support and assisting in capacity building for countries willing to make use of carbon pricing reduces the barriers of implementation and speeds up the implementation process. This support can be provided bilaterally (e.g. between existing and emerging ETSs) or through multilateral initiatives. Moreover, learning from the design of other schemes can help to improve the effectiveness of new carbon pricing schemes.

Facilitating the introduction of carbon pricing instruments by reducing the implementation barriers will remain important in the coming years because more and more countries are considering the use of pricing instruments (World Bank and Ecofys, 2018[5]). Hence, multilateral initiatives, including the Carbon Market Platform, the Carbon Pricing Leadership Coalition, and the PMR, may intensify their efforts to meet the increased demand for dissemination of knowledge and technical know-how. Fostering the process of exchanging ideas and mutual learning would facilitate the implementation of effective pricing instruments in an increasing number of countries.

5.2. Facilitate the implementation of internal carbon prices

Internal carbon prices for the evaluation of public projects can broaden the economic coverage of carbon pricing by including the public sector. Internal carbon prices used in cost-benefit analysis (CBA) of public projects complement external carbon prices for the private sector and aligns the incentives of governments with climate change mitigation goals. A number of OECD countries are using internal carbon prices, particularly in projects related to transport and – to a lower extent in the energy sector.

Increasing the price level and broadening the economic coverage of internal carbon pricing can improve the effectiveness of this instrument and can help to channel public investments into low-carbon alternatives. Currently, most of the unit values for the social costs of carbon applied are below EUR 40, the lower end of the price range in the short term to be consistent with reaching the targets of the Paris Agreement. Raising the price level would make carbon-intensive public investments relatively more expensive and would, thus, benefit low-carbon investment projects. Similarly, internal carbon prices could be applied more broadly, including in public appraisal projects outside the transport and energy sector to increase the coverage.

International co-ordination on internal carbon prices in terms of sharing best-practice approaches and encouraging other governments to make use of internal carbon pricing in CBAs can broaden the geographical coverage of this instrument. Accounting for and valuing GHG emissions in CBAs for public projects still faces some implementation barriers, particularly related to the estimation of direct and indirect project-based emissions and to the determination of the unit cost of carbon applied. Knowledge sharing in terms of providing guidelines and exchanging best-practices can help other jurisdictions, including sub-national and local governments, to successfully implement internal carbon prices in the ex-ante evaluation of public projects.

5.3. Phasing out inefficient fossil fuel subsidies

Support for fossil fuels through direct transfers to consumers or producers or through preferential tax treatments lead to artificially low prices for energy products, resulting in investment and consumption decisions that are biased towards high-carbon alternatives. Since fossil fuel subsidies encourage over-consumption of fossil fuels and increase CO_2 emissions, each country benefits from other countries reforming their subsidy structure. G20 and APEC countries have made joint commitments to phase out "inefficient fossil fuel subsidies that encourage wasteful consumption over the medium term" (G-20, 2009[52]). As a first step, G20 and APEC countries started collecting data on their national fossil fuel support, a process that enabled the exchange of information and experience. Starting in 2013, both country groups also initiated voluntary peer-reviews of their fossil fuel support.

The peer-reviews substantially expanded the public knowledge on existing fossil fuel support while helping governments to get a better understanding of their energy policy. For example, China invested more than a year in the preparation of its report, thereby gaining a better understanding of the aspects of its energy policy that favoured fossil-fuel production or consumption by the consultation of other stakeholders such as academics, internal and foreign experts, and its energy industry. The participation in the review team also helped country experts from foreign jurisdictions to better understand the variety of support measures and to learn about the barriers other countries faced in the reform process as well as about the solutions that worked best.

Widening and accelerating the peer-review process can increase reform momentum and can benefit a larger number of countries, including outside G20 and APEC. The current examples of completed peer reviews have demonstrated that they bring mutual benefits to both the reviewer and the reviewed countries. Expanding the reviews at a faster pace may benefit more countries, thereby accelerating reform momentum to phase out inefficient fossil fuel subsidies. Accelerating reform momentum is particularly important when bearing in mind that the current global support of fossil fuels is still multiple times higher than the revenues from all carbon pricing schemes combined.

Phasing out inefficient FFS calls for multiple policy actions: First, tracking countries' reform progress and maintaining reform momentum requires maintaining and expanding a database on government's support for fossil fuels. Comprehensive data on fossil fuel support has been already collected for most G20 and APEC countries, spanning some years of observations. Regular, up-to-date, publicly available, and comparable information on reform progress helps maintaining reform momentum (OECD, 2017[4]). This information also enhances the understanding of the heterogeneous impacts of FFS, allowing for more precise targeting of future reforms. Second, identifying the barriers to reforms and sharing experience facilitates the reform progress and its effectiveness in other countries. Third, a common understanding of key definitions, including “subsidy”, “inefficient”, and “wasteful consumption”, eases co-ordination on reforms that can hamper the harmonisation of data and policy reforms.

5.4. Sectoral approaches to carbon pricing

Well-designed sectoral approaches between jurisdictions can reduce GHG emissions while addressing competitiveness concerns without comprising economic growth prospects. This makes these approaches a promising means for higher ambition in the reduction of GHG emissions and for the sector-wide implementation of carbon pricing instruments, in particular for, but not limited to, energy-intensive trade-exposed (EITE) sectors such as steel, cement, and aluminium. These sectors are characterised by a high share of energy costs on total production costs while being subject to international competition.

Some EITE sectors have been co-operating internationally under involvement of public stakeholders to reduce GHG emissions. While carbon pricing has not been implemented in any of these sectors in form of a specific sectoral approach[15], efforts to reduce GHG emissions include knowledge sharing of best-available technologies to improve the carbon intensity of plants and the definition of international standards for calculating CO_2 emissions (e.g. ISO 14404:2013 for the steel industry). Precise measurement of carbon emissions can facilitate the implementation of carbon pricing.

Focussing on specific industry sectors can facilitate the implementation of carbon pricing while raising the levels of prices where emissions are already priced, thereby increasing cost-effectiveness. Currently, 64% of emissions in the industry sector are not priced at all while only 2% are priced above EUR 30. In countries where the industry sector is covered by carbon pricing, most firms benefit from complementary measures such as preferential tax treatment or generous allocation of free allowances to address the adverse impact of carbon pricing on international competitiveness. International co-ordination can help to address these adverse impacts by levelling the playing field for EITE sectors across jurisdictions. Policy makers could use existing fora or create new platforms for information exchange and co-ordination.

Under the auspices of the UNFCCC, Member States of the ICAO have agreed to stabilize the sectoral GHG emissions at the 2020 level, while Member States of the IMO committed to reduce GHG emissions from global shipping to at least 50% by 2050 relative to 2008. The ICAO announced the use of a market-based approach (CORSIA), requiring airline operators to offset the growth of emissions after 2020, e.g. by purchasing emission units generated from emission reductions in other sectors and countries.

CORSIA has raised a lot of questions that need to be addressed in the upcoming negotiations of the Paris rulebook and thereafter. Given the expected growth in demand for international aviation and the limited technological options to improve emission intensity,

[15] Some EITE sectors are covered by broader carbon pricing instruments. For example, the EU ETS has covered steel and cement plants from 2005 and included aluminium plants from 2013.

the international aviation sector will become one of the largest buyers of carbon offsets post 2020. Thus, robust quality standards for carbon credits are crucial to safeguard environmental integrity. Furthermore, the UNFCCC – potentially in co-operation with ICAO - needs to provide guidance on how to account for countries' emissions reductions that are purchased by CORSIA and how to avoid double counting, i.e. to ensure that emissions reductions are only counted once: either for the host country's NDC or for CORSIA. In the long run, it remains to be seen where the supply of offsets comes from once countries are increasingly decarbonising their economies.

For the international maritime transport sector, it remains to be seen whether Member States agree on policy instruments to achieve the long-term emission reduction target and which policy instruments will evolve in the international dialogue. Given the precise reduction target, a market-based approach seems to be most appropriate as it can deliver the desired emissions reduction in a cost-effective way.

5.5. International emissions trading and climate crediting mechanisms

International trading of carbon units through crediting mechanisms or under the mechanism of Article 6 of the Paris Agreement can bring mutual benefits for all parties involved. Crediting mechanisms or offsets allow regulated entities to meet part of their emission-reduction obligation through purchasing carbon credits generated by emission reductions in other jurisdictions or sectors from other parties. Crediting mechanisms such as the Clean Development Mechanism (CDM) can reduce mitigation costs for emitters and channel finance towards low-cost abatement options, primarily in developing countries. International emissions trading under the auspices of the UNFCC is likely to continue under the rules of Article 6 of the Paris Agreement, but the rule book of the Paris Agreement first needs to be finalised.

The CDM has successfully reduced mitigation costs and has channelled finance into low-carbon projects, but has also triggered several discussions about environmental integrity issue. The CDM has generated more than 2 billion CER units, most of which have been surrendered in carbon markets, which has led to savings in mitigation costs of several million Euros (Trotignon, 2012[73]). However, environmental integrity of CDM projects has always been a serious concern. While some CDM projects may not have been additional - meaning that they would have been realized also in the absence of the CDM – CDM credits may also have triggered perverse incentives to increase emissions beforehand.

The future use of climate crediting mechanisms is uncertain, but international trading of emission units under the UNFCCC will continue under Article 6 of the Paris Agreement. The differentiation between Annex I countries (that were subject to emission reductions under the Kyoto Protocol) and non-Annex I countries (that were not) does not persist under the Paris Agreement. Instead, in the Paris Agreement each country committed to mitigation efforts expressed through the submission of NDCs. Hence, offset trading under the CDM will be replaced by trading international mitigation outcomes (ITMO)s that are accounted against countries NDCs.

Article 6 of the Paris Agreement will have a significant impact on the future of international emissions trading under the UNFCCC, but the concrete rules still need to be finalised. Crucial elements to be decided include eligibility criteria for projects, robust accounting standards, the vintage of reduction units, and baselines, including those of countries' NDCs (see Section 4.5 for more details).

As the CDM, international emissions trading under Article 6 may suffer from an oversupply of ITMOs, but a price floor may increase investment certainty into low-carbon projects. Only a limited number of countries expressed interest in buying (relative to selling) ITMOs on the international carbon market in their NDCs. This may lead to an oversupply of ITMOs and can is likely to result in low market prices (see Figure 4.4). Minimum prices for ITMOs may guarantee investors into low-carbon projects a certain return on investment, but may exacerbate the oversupply of ITMOs.

5.6. Co-ordinating on minimum carbon prices

International co-ordination on minimum carbon prices can lead to some convergence of carbon prices, thereby increasing economic efficiency, leading to lower overall mitigation costs. Minimum carbon prices can be implemented in multiple forms, including setting minimum carbon tax rates or excise tax rates on fossil fuels, or implementing floor prices in ETSs.

Co-ordinating on minimum rates for these taxes may be a first and important step towards the convergence of effective carbon rates. Excise taxes on energy products such as oil, gas, and coal form the major part of effective carbon rates in most countries, accounting for more than 90% of the effective carbon rate in most sectors16 (OECD, 2018[7]). Minimum tax rates lead to some harmonization of prices across jurisdictions without preventing countries from setting higher tax rates, showing higher ambition or addressing country-specific circumstances. The European Union implemented minimum excise rates for most energy products with the Directive 2003/96/EC in 2003, which resulted in a harmonization of energy taxes across its Member States. While some countries impose taxes at the level of the minimum rates, other countries' tax levels exceed the minimum rates by a considerable amount.

The approach of the European Union could be extended towards other country groups. This would have a considerable effect on the harmonisation of energy prices and effective carbon rates because energy taxes are already in place in many countries covering many sectors whereas the coverage of explicit carbon pricing instruments, including ETSs and carbon taxes, is considerably lower.

Minimum excise rates on different fossil fuels are more cost-effective if their implicit carbon rates are homogeneous across energy products and economic sectors. Currently, the implicit minimum carbon rates in the European Union differ substantially between each other. While the minimum carbon rate is 140 EUR/t CO_2 for petrol, it is only 7.5 EUR/t CO_2 for gasoil for heating. Convergence of minimum carbon rates would increase cost-effectiveness, but may not be optimal if the energy taxes reflect other negative externalities such as local air pollution or congestion. However, an efficient tax system in line with the Tinbergen rule would address each of the negative externalities by a separate policy instrument (Tinbergen, 1952[116]). For example, an efficient tax structure for road transport would require, among others, congestion charges as well as distance charges differentiated according to vehicles' emission profiles and to exposure to pollution to address local air pollution (Van Dender, 2018 forthcoming[117]).

[16] The share of excise taxes on the effective carbon rate for sectors are Road transport (99%), Agriculture & fisheries (98%), Offroad transport (96%), Residential and commercial (93%), Industry (62%), and Electricity (19%)(see Table 2.2 OECD (OECD, 2018[132])).

Minimum carbon prices on explicit pricing instruments have been implemented by a number of jurisdictions, including the RGGI, the California and Quebec ETS, and Canada. The Pan-Canadian Framework on Clean Growth and Climate Change (PFC) - in co-operation between the Canadian Federal government and the Canadian Provinces - establishes a federal benchmark that ensures carbon pricing is in place in all jurisdictions in Canada, but leaves the Provinces flexibility regarding the choice of the pricing instrument (see Box 4.1). The PFC has the potential to be applied beyond Canada for a group of countries willing to harmonize their explicit carbon prices. Leaving countries flexibility in the choice of their pricing instrument allows them to adopt the instrument that is most appropriate to their country-specific circumstances. Moreover, requiring countries to meet only a minimum price does not compromise more ambitious countries to set higher carbon prices.

Carbon floor prices for specific sectors can effectively reduce sector-specific GHG emissions. For example, the UK Carbon Price Floor that applies for the electricity sector has led to a substantial reduction in coal consumption in the electricity sector. Currently, carbon price floors for the electricity sector are also considered by other EU ETS member states, including Austria, France, the Netherlands, and some Nordic countries (ICAP, 2018[118]). For example, the Dutch government published a draft law that envisions to levy a floor price on electricity producers reaching 43 Euros by 2030 (Carbon Market Watch, 2018[119]). Adopting this law may help spurring the ongoing conversations with other EU member states, including France and Germany, to develop a regional minimum carbon price for EU ETS participants. However, unilateral national carbon price floors may lead to a fragmentation of the EU ETS and may decrease the efficiency of the EU ETS (since it leads to divergence of price levels away from a uniform European-wide carbon price) without substantially reducing GHG emissions across the EU as emissions shift from high-price to low-price countries (IETA, 2018[120]).

5.7. Direct linking between carbon markets and other price instruments

Direct linking of carbon markets leads to full price convergence, thereby implying that a given mitigation target is met at the lowest economic cost. Equal carbon prices across linked jurisdictions level the playing field for firms in the co-ordinating partner economies, but competitiveness concerns against third party countries may still require the use of complementary measures such as allocating emissions free of charge.

As of today, some direct linkages have taken place: Norway, Iceland, and Liechtenstein joined the EU ETS in 2008, Croatia joined in 2013, while Switzerland and the EU ETS concluded negotiations with the link potentially becoming operational as of 2020 (ICAP, 2018[121]); Tokio linked with Saisuma in 2011; California and Quebec established a link in 2014. One of the most important factors for existing links seems to be geographic proximity. Nearby jurisdictions tend to have similar environmental goals and economic conditions, a history of productive engagement on other issues, and familiarity with and connections between each other's regulatory and political systems – factors likely to facilitate linkage.

Similarity of emissions reduction targets and prices seems to be decisive for linking as well. For example, the California Air Resources Board mentioned the low carbon price level in the EU ETS as one factor impeding linkage with the Californian ETS (Kahn, 2013[122]). It is also argued that California has not yet established a link to the RGGI because of the low prices in the RGGI (Burtraw et al., 2013[123]). Conversely, the link between California and Quebec is established among jurisdictions that have signalled strong commitment to deep emission reductions indicated through comparable price trajectories of the minimum auction price.

Linking can be expected to gain momentum in the future, but requires co-ordination on many key design principles beforehand. As more and more ETSs are evolving globally, linking may be a promising approach to increase economic efficiency. This is particularly true for rather small ETSs for which the gains of linking are likely to be the largest due to the increases of liquidity and of heterogeneity of abatement costs. A successful link between ETSs requires co-ordination on multiple key design principles to address and overcome the barriers associated with linking, including the relative stringency of the cap, differences in the desired price range (or emissions trajectory), and loss of regulatory control (see Section 4.7 for a deeper discussion).

If unrestricted linking is not (yet) politically or technically feasible, restricted linking, including quantity limits, quotas or exchange rates, may be a first step towards direct linking. Quantity limits restrict the amount of certificates from other jurisdictions for compliance, leading to partial price convergence (Lazarus et al., 2015[124]). Many ETSs, including the EU ETS and California, apply quantity limits on the use of offsets. Quantity limits ensure that a predetermined fraction of the emission reduction in a system is abated domestically, but are less efficient than direct linking as they prevent full price convergence. Other forms of restrictions include banning certain types of permits, or applying a discount factor or exchange rate.

Linking agreements may also provide for clear and transparent rules with respect to delinking, which may be relevant when political preferences of linked jurisdictions change (Mehling and Haites, 2009[90]). For example, as reaction to Ontario's cancellation of the link with the joint Californian and Quebec scheme, California's Air Resources Board (ARB) released draft amendments for the cap-and-trade program, specifically addressing delinking. This draft provides, among others, options to safeguard environmental integrity of the scheme in the case of delinking. In particular, the draft includes provisions for retaining future allowances to equalize a potential net surplus of imported permits from the delinking jurisdiction (ICAP, 2018[125]).

5.8. Carbon market clubs and carbon pricing clubs

Carbon clubs, either in form of carbon pricing clubs or carbon markets clubs, aim at increasing members' ambition towards climate change mitigation while encouraging participation of non-members. Carbon clubs provide benefits for members that go beyond the benefits associated with price convergence while (potentially) using complementary measures to increase the costs of non-memberships, both of which encourage participation and allow for higher ambition in reducing GHG emissions. These complementary measures include border carbon adjustments (BCA) (Keohane, Petsonk and Hanafi, 2017[105])or uniform percentage trade tariffs (Nordhaus, 2015[106]). However, some major barriers for both proposals remain, particularly with respect to the feasibility of BCAs and the use of trade tariffs in light of international trade treaties and the global economic relations (see Box 4.2).

Carbon clubs can evolve in different ways. A carbon markets or pricing club might be launched under the auspices of the UNFCCC, but a more likely approach would be to create the club as a complement to the UNFCCC. The club would not be structured as a formal treaty, so that participation of national, subnational or regional jurisdictions could be possible. The non-formal nature of the club would also enhance the potential of enhancing participation. However, the non-formal nature also means that participation is voluntary, so that (economic) incentives both for non-members to join the club and for members to comply with the rules of the club are important.

Carbon clubs may grow simultaneously besides each other. Each club may grow organically starting from a small number of countries that design the structure of the club and invite other countries to join. Currently, some club-like structures, including the Western Climate Initiative (WCI), the RGGI, or the Carbon Pricing in the Americas Declaration already exist. Moreover, there are other regional initiatives, such as the co-ordination on carbon pricing in the European Union, and the recently formed West-African Alliance on Carbon Markets and Climate Finance.17 These regional initiatives could initially evolve besides each other, but may also start co-ordinating their efforts across regions to allow for deeper co-operation in the future. This may eventually lead to a world-wide carbon club that encompasses the regional clubs.

Carbon clubs have the potential to successfully address free-rider incentives thereby enabling ambitious mitigation efforts and high voluntary participation of countries, both of which can avoid dangerous climate change. While the academic approaches discussed above are appealing in terms of its environmental outcomes, it would require changes to the landscape of existing international treaties and global economic relations. However, if the Paris Agreement and its successor treaties do not deliver the results necessary for preventing dangerous climate change, these proposals might gain some momentum, including outside academia.

5.9. Towards a single global carbon price?

A single global carbon price is desirable from an economic efficiency point of view, but raises serious distributional concerns. In theory and abstracting from all other externalities and market failures, a single global carbon price would be the first best-solution for achieving a global mitigation target at the lowest mitigation cost. However, a single global carbon price is not desirable from an equity point of view because the major burden of climate mitigation is shifted towards low-income countries that have most of the low-cost abatement options. In theory, financial transfers from high-income to low-income transfers could compensate low-income countries, but the magnitude of these transfers is likely to be opposed by high-income countries' general public (High-Level Commission on Carbon Prices, 2017[8]).

Regardless of the distributional aspect, a global carbon price could emerge through a global carbon market with a comprehensive coverage of all GHG emissions. This global carbon market could evolve from bottom-up emission trading schemes, which can establish links with each other to form (regional) networks of linked schemes. These regional linked schemes could initially co-exist besides each other before eventually merging to a global market. Carbon market clubs (see Section 4.8) can provide the necessary infrastructure and can facilitate the linking process while encouraging participation of non-participants. Alternatively, the global carbon market could evolve from international emissions trading of countries' NDCs. Article 6 of the Paris Agreement provides mechanism for transferring

[17] The West African Alliance on Carbon Markets and Climate Finance aims to enhance the participation of member countries in international carbon markets. Member countries include Benin, Cape Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Mauretania, Niger, Nigeria, Liberia, Burkina Faso, Sierra Leone, Senegal, and Togo. For more information on the see https://www.westafricaclimatealliance.org/.

emission units between countries, e.g. the internationally transferred mitigation outcomes (ITMO) mentioned in Article 6.2 (see Section 4.5). Trading ITMOs could establish a global carbon market with a single global carbon price in the future. Yet, to start with, countries still need to finalise the exact rules of Article 6 of the Paris Agreement.

A global carbon price could also emerge from international negotiations on carbon prices instead of emission quantities as proposed recently in the academic community (Weitzman, 2014[126]). This would imply moving away from the currently in place quantity-based format of the negotiations towards a price-based format, which has triggered some discussion in the academic community recently (Box 5.1). Since countries would negotiate over prices rather than quantities, any such format also needs to consider international support for climate action in low-income countries in parallel. Once Parties agreed on prices to be the organising principle in the negotiations, countries could vote on the exact price level in a 'World Climate Assembly', thereby determining the global carbon price in a democratic way (Weitzman, 2017[127]).

Box 5.1. Prices versus quantities in the international negotiation process

There has been a debate about the question of negotiating on prices rather than on quantities in international climate negotiations in the academic community recently. Both approaches have pros and cons. While a quantity-based approach connected to international emission trading automatically involves transfers of financial means through the market mechanism, a price-based approach may address the free-rider incentives more efficiently, leading to more ambitious price and mitigation levels.

Negotiating over prices rather than quantities can successfully address the free-rider problem inherent to global climate change (Weitzman, 2014[128]), but has some undesired regional distributional consequences. Negotiating over a binding uniform carbon price has the advantage that countries internalize the negative climate externality in their negotiation position (Weitzman, 2014[129]):[18] A higher carbon price increases the domestic abatement costs, but also induces all other countries to expand their mitigation effort. This reduces the damage from global warming and, thus, provides incentives to agree on a higher price level relative to the price that would have resulted from negotiating over quantities. However, negotiating over prices can have undesired regional distributional consequences in the absence of international transfers. Abstracting from international transfer between countries would imply to impose the major burden of climate change mitigation on low-income countries. In addition, this could be detrimental to the solution of more pressing needs such as poverty eradication. Hence, a single global carbon price in the absence of

[18] The proposal of (Weitzman, 2014[136]) foresees an approach in which countries directly negotiate over a binding minimum carbon price. A carbon price is a cost-effective tool and a good approximate indicator of a country's mitigation effort so that it is well suited for comparing the burden of carbon pricing across all countries. Countries would retain all their tax incomes domestically. Although this is not a crucial feature of the proposal, it eliminates any further negotiation dimension apart from the carbon price. Countries would vote on the level of the carbon price with the price level of the median voter to be implemented by all countries. To ensure enforcement, countries could apply border carbon adjustments on imports of non-complying countries.

transfers is certainly not feasible nor desirable in the absence of major international transfers.

Conditional international transfers from high-income countries to low-income countries may solve the distributional problem. The condition would imply that low-income countries accept a higher binding price for carbon in exchange for receiving financial transfers (MacKay et al., 2015[130]). This mechanism aims at encouraging low-income countries to raise their ambitions regarding the level of the carbon price while high-income countries would benefit from increased global mitigation effort. For example, transfers can be directly proportional to the agreed carbon price so that a reduction in the level of ambition would cause a loss of international support, thereby providing incentives for all transfer-receiving countries to raise ambition.

A global carbon market based on country-specific reduction targets can also solve the distributional problem, but the aggregate mitigation effort may not be ambitious enough. A global carbon market with an appropriate and fair distribution of emission reduction targets automatically transfers financial means from high-income countries with high abatement costs to low-income countries with rather low abatement costs to compensate the latter for part of the mitigation cost (Keohane, 2009[131]) However, the question is whether countries can agree on a distribution of emission reduction targets, which is not only fair, but also sufficiently ambitious to tackle climate change effectively. The reason is that each country has an incentive to free-ride on the mitigation effort of the others by submitting a sub-optimal emission reduction target from a global welfare perspective when countries negotiate over quantities. As a result, the combined mitigation effort is likely to be rather unambitious when countries agree to an international binding treaty based on quantities.

6. Conclusion

Carbon pricing is the building block of any feasible mitigation pathway to meet the 'well-below 2 degree' target from the Paris Agreement as it represents a cost-effective instrument that encourages emitters of GHG emissions to reduce their emissions. Pricing carbon can give firms and households economic incentives for reducing GHG emissions, channelling finance into low-carbon technologies, and triggering investments in research of development of new and better low-carbon technologies.

Carbon pricing has gained momentum ultimately, but the coverage and current levels of carbon pricing are still far away from sending the price signal needed for triggering investments necessary for a decisive transition to a low-carbon economy. More than half of the currently existing carbon pricing schemes have been implemented in the last six years, while more schemes are going to be implement in the coming years. However, 46% of energy-related CO_2 emissions are not priced at all. For OECD and G20 countries, the carbon pricing gap, i.e. the gap between the effective carbon rate and EUR 30, is 76.5%, while this figure is substantially higher when not accounting for the road sector. Moreover, the carbon pricing gap varies considerably across countries and economic sectors.

International co-ordination on carbon pricing can benefit all co-operating jurisdictions, thereby helping them to increase both the coverage and the levels of domestic carbon pricing. Benefits from international co-operation include economic benefits in terms of saving mitigation costs and levelling the playing field, environmental benefits in terms of safeguarding environmental integrity, political benefits through sending a political signal of commitment, that can eventually spill-over to other jurisdictions and can encourage carbon pricing there, and fiscal benefits through more ambitious price levels and less need for complementary measures both of which increase fiscal space and can be used for reducing distortionary taxes elsewhere in the economy.

International co-ordination on carbon pricing can help to deliver on the NDCs in a cost-effective way and can create a 'web of carbon pricing schemes' that has the potential to raise countries' ambition over time. Co-ordination may involve jurisdictions adopting multiple of the options outlined in this paper simultaneously at multiple levels. This simultaneous use of different options by different actors, co-ordinating with different partners can create a 'web of carbon pricing schemes'. Expanding this web in form of an incremental and stepwise approach may have the potential to create and maintain political momentum for deeper and deeper co-ordination, finally leading to more stringent climate action.

The levels of co-ordination discussed in this working paper include:

- Facilitating the creation of new carbon pricing schemes can expand and accelerate the geographical coverage of carbon pricing schemes globally. Supporting governments by capacity development and sharing best-practice approaches reduces the implementation barriers, thereby facilitating and accelerating the implementation of new carbon pricing schemes. This can result in a virtuous cycle, encouraging other jurisdictions to implement some form of carbon pricing and raising the ambitions of jurisdictions with existing pricing schemes. As more and more jurisdictions are considering the implementation of carbon pricing instruments, providing support will remain important in the coming years.

- Facilitating the implementation of internal carbon prices for the evaluation of public projects can broaden the economic coverage of carbon pricing by including the public sector. It can ensure that climate considerations are taken into account by public governments to align incentives in the public sector. International co-ordination on internal carbon prices through sharing best-practice approaches, e.g, with respect to emissions accounting and determining the unit costs of carbon can reduce the implementation barriers and can broaden the geographical coverage of internal carbon prices.
- Phasing out inefficient fossil fuel subsidies can enhance a countries' policy coherence with respect to its climate objectives by correcting misaligned price signals. Fossil fuel reforms have the potential to free up scarce fiscal resources that could be used more efficiently elsewhere while being generally non-regressive. Maintaining and expanding a database on government's support for fossil fuels, including through the reciprocal peer-reviews of countries' national fossil fuel support, is a pre-condition for maintaining reform momentum as well as for identifying the barriers to and increasing the effectiveness of reforms.
- Sectoral approaches to carbon pricing can mitigate GHG emissions in that sector while addressing both competitiveness and economic development concerns. Focusing on a specific sector reduces the number of stakeholders, which may facilitate agreement and lead to more ambitious mitigation outcomes while broadening the participation, potentially including countries without existing carbon pricing policies. While some sectors have been co-operating internationally under involvement of public stakeholders to reduce GHG emissions, others (international maritime and international aviation) agreed to fixed emissions reductions targets. The use of carbon pricing enables achieving these targets in a cost-effective way.
- International emissions trading and climate crediting mechanisms can reduce the abatement costs of emitters and countries and transfer financial means for mitigation action to low-abatement cost countries and sectors. Crediting mechanisms, such as the Clean Development Mechanism (CDM), have successfully reduced abatement costs and finance low-carbon projects in non-Annex I countries, but have also raised concerns regarding environmental integrity of offset trading. Lessons learnt from the CDM need to be taken into account when finalizing the rule book of Article 6 of the Paris Agreement, the successor of the CDM. Many open questions for the finalisation of the rule book remain, including with respect to robust accounting standards to avoid double counting, eligibility criteria for projects, and baselines, including those used for determining countries' NDCs.
- Co-ordinating on minimum carbon prices – e.g. on explicit carbon taxes, floor prices for emission trading schemes (ETS) or excise taxes for fossil fuels - leads to some convergence of carbon prices, thereby increasing economic efficiency. Moreover, minimum prices do not prevent jurisdictions from imposing higher effective carbon rates. Co-ordinating on minimum excise taxes on energy products, as done in the European Union, may have the largest impact on price convergence of effective carbon rates in the short run as most countries already have excise taxes in place. For explicit carbon pricing instruments, the approach of the Pan-Canadian Framework on Clean Growth and Climate Change seems to be most promising since it sets a federal benchmark, but leaves the Provinces enough leeway to choose

their preferred pricing instrument. Implementing floor prices for (linked) ETSs can reduce the permit price volatility, thereby increasing investment certainty of low-carbon projects.

- Direct linking of ETSs can maximise the economic efficiency gains due to full convergence of the carbon price between linked participants, but also requires co-ordination on key design features beforehand. In addition, direct linking can increase the liquidity of a market while locking-in commitment. Linking ETSs requires harmonization of key design elements and political choices, including the relative stringency of the cap (that is informative for the expected price range of the permit price) and cost-containment measures (that spill-over from one scheme to the other). As more and more ETSs are evolving globally, linking – particularly linking between rather small ETSs where gains are highest – can be expected to gain momentum in the coming years. If direct linking between ETSs is not yet feasible, restricted linking, e.g. by using quotas, may be a first step towards direct linking.
- Carbon pricing clubs or carbon markets clubs aim at broadening the geographical coverage carbon pricing by encouraging participation. First, they provide benefits for members that go beyond the benefits derived from price convergence. Second, they may employ complementary measures that increase the costs of non-memberships, thereby encouraging participation, allowing for higher ambition in reducing GHG emissions. Some club-like structures and regional initiatives on carbon pricing (WCI, RGGI, EU ETS, etc.) already exist and could be the starting point for more and deeper co-operation. These regional clubs could broaden the participation and eventually start co-ordinating their efforts across regions, finally resulting in a global carbon pricing club.
- A single global carbon price would be - in theory - the first-best solution as it represents the most cost-effective way to mitigate GHG emissions, but may not be desirable from an equity point of view. Having the same carbon price across regions would equalize marginal abatement costs and reduce a given (global) emission reduction target at the lowest mitigation cost. However, a single global carbon price would shift the major burden of climate mitigation towards low-income countries where most of the low-cost abatement options are located.

References

Acemoglu, D. et al. (2012), "The Environment and Directed Technical Change", *American Economic Review*, Vol. 102/1, pp. 131-166, http://dx.doi.org/10.1257/aer.102.1.131. [12]

APEC (2009), *A New Growth Paradigm for a Connected Asia-Pacific in the 21st Century*, Asia-Pacific Economic Co-operation, 14-15 November 2009. [53]

Arlinghaus, J. and K. van Dender (2017), "The environmental tax and subsidy reform in Mexico", *OECD Taxation Working Papers*, No. 31, OECD Publishing, Paris, https://dx.doi.org/10.1787/a9204f40-en. [51]

Australian Government (2014), *Emissions Reduction Fund White Paper*, http://www.environment.gov.au/system/files/resources/1f98a924-5946-404c-9510-d4403042801f/files/erf-white-paper.pdf (accessed on 22 October 2018). [16]

Baron, R., B. Buchner and J. Ellis (2009), "Sectoral Approaches and the Carbon Market", *Climate Change Expert Group Paper*, No. 2009(03), https://www.oecd-ilibrary.org/fr/environment/sectoral-approaches-and-the-carbon-market_5k4559g5snzq-en (accessed on 29 October 2018). [75]

Baron, R. et al. (2007), "Sectoral Approaches to Greenhouse Gas Mitigation: Exploring Issues for Heavy Industry", *IEA Information Paper*, https://www.iea.org/publications/freepublications/publication/Sectoral_Approach_Info_WEB.pdf (accessed on 26 April 2018). [61]

Barrett, S. (1994), "Self-Enforcing International Environmental Agreements", *Oxford Economic Papers*, Vol. 46, pp. 878-894, https://www.jstor.org/stable/2663505?seq=1#metadata_info_tab_contents. [113]

Belgian Federal Climate Change Section et al. (2018), *Belgian National Debate on Carbon Pricing: Final Report*, https://www.climat.be/files/2615/3268/2882/National_Carbon_Pricing_Debate_-_Final_Report.pdf (accessed on 18 December 2018). [41]

BMUB (2017), *Carbon Pricing: Using Market-based Mechanisms to Mitigate Climate Change*, https://www.bmu.de/en/publication/carbon-pricing-using-market-based-mechanisms-to-mitigate-climate-change/ (accessed on 16 October 2018). [85]

Boemare, C. and P. Quirion (2002), "Implementing greenhouse gas trading in Europe: lessons from economic literature and international experiences", *Ecological Economics*, Vol. 43/2-3, pp. 213-230, http://dx.doi.org/10.1016/S0921-8009(02)00213-6. [102]

Buchanan, S. (2018), *What you need to know about Ontario's carbon pricing drama - Environmental Defence*, https://environmentaldefence.ca/2018/06/20/17288/ (accessed on 3 August 2018). [96]

Burniaux, J. et al. (2009), "The Economics of Climate Change Mitigation: How To Build The Necessary Global Action in a Cost-effective Manner", *OECD Economic Working Papers*, Vol. No. 701, http://www.oecd.org/eco/working_papers. [71]

Burtraw, D. et al. (2017), *Expanding the Toolkit : The Potential Role for an Emissions Containment Reserve in RGGI RFF REPORT*, https://www.semanticscholar.org/paper/Expanding-the-Toolkit-%3A-The-Potential-Role-for-an-Burtraw-Holt/8f19c845de48a805580edbfd51b50e8916875d5a. [104]

Burtraw, D. et al. (2013), *Linking by Degrees: Incremental Alignment of Cap-and-Trade Markets*, http://www.rff.org/research/publications/linking-degrees-incremental-alignment-cap-and-trade-markets. [123]

Calel, R. and A. Dechezleprêtre (2016), "Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market", *Review of Economics and Statistics*, Vol. 98/1, pp. 173-191, http://dx.doi.org/10.1162/REST_a_00470. [11]

Carbon Market Watch (2018), *Netherlands fits its new price floor*, https://carbonmarketwatch.org/2018/08/21/netherlands-fits-its-new-price-floor/ (accessed on 24 October 2018). [119]

Carbon Pricing Leadership Coalition (2017), *Report of the High-Level Commission on Carbon Prices I*, http://www.carbonpricingleadership.org. [23]

Carraro, C. and D. Siniscalco (1993), "Strategies for the international protection of the environment", *Journal of Public Economics*, Vol. 52/3, pp. 309-328, http://dx.doi.org/10.1016/0047-2727(93)90037-T. [3]

Clapp, C. and A. Prag (2012), "Projecting Emissions Baselines for National Climate Policy: Options for Guidance to Improve Transparency", *OECD/IEA Climate Change Expert Group Papers*, No. 2012(04), https://www.oecd-ilibrary.org/environment-and-sustainable-development/projecting-emissions-baselines-for-national-climate-policy_5k3tpsz58wvc-en (accessed on 29 October 2018). [84]

Climate Strategies (2016), *Carbon Market Clubs and the New Paris Regime*. [9]

Condon, M. and A. Ignaciuk (2013), "Border Carbon Adjustment and International Trade: A Literature Review", *OECD Trade and Environment Working Papers*, No. 2013/6, OECD Publishing, Paris, https://dx.doi.org/10.1787/5k3xn25b386c-en. [107]

Cosbey, A. et al. (2012), "A Guide for the Concerned: Guidance on the Elaboration and Implementation of Border Carbon Adjustment", *Entwined Policy Report*, No. No. 03, http://dx.doi.org/10.2139/ssrn.2178312. [111]

Cramton, P. et al. (2017), "Global carbon pricing", in Cramton, P. (ed.), *Global carbon pricing : the path to climate cooperation*, The MIT Press, Cambridge, Massachusetts, https://mitpress.mit.edu/books/global-carbon-pricing. [30]

Dechezleprêtre, A., D. Nachtigall and F. Venmans (2018), "The joint impact of the European Union emissions trading system on carbon emissions and economic performance", *OECD Economics Department Working paper*, Vol. 1515, http://dx.doi.org/10.1787/18151973. [58]

Dechezleprêtre, A. and M. Sato (2017), "The Impacts of Environmental Regulations on Competitiveness", *Review of Environmental Economics and Policy*, Vol. 11/2, pp. 183-206, http://dx.doi.org/10.1093/reep/rex013. [26]

Edenhofer, O. et al. (2017), "Decarbonization and EU ETS Reform: Introducing a price floor to drive low-carbon investments Policy Paper", *MCC Policy Paper*, https://www.mcc-berlin.net/fileadmin/data/C18_MCC_Publications/Decarbonization_EU_ETS_Reform_Policy_Paper.pdf. [87]

Ellis, J. and D. Tirpak (2006), "Linking GHG emission trading schemes and markets", OECD, http://www.oecd.org/env/cc. [97]

Environment and Climate Change Canada (2016), *Pan-Canadian Approach to Pricing Carbon Pollution - Canada.ca*, https://www.canada.ca/en/environment-climate-change/news/2016/10/canadian-approach-pricing-carbon-pollution.html (accessed on 10 September 2018). [14]

European Commission (2015), *Guide to Cost-Benefit Analysis of Investment Projects*, European Union, http://dx.doi.org/10.2776/97516. [46]

Felder, S. and T. Rutherford (1993), "Unilateral CO2 Reductions and Carbon Leakage: The Consequences of International Trade in Oil and Basic Materials", *Journal of Environmental Economics and Management*, Vol. 25/2, pp. 162-176, http://dx.doi.org/10.1006/JEEM.1993.1040. [24]

Flachsland, C., R. Marschinski and O. Edenhofer (2009), "To link or not to link: benefits and disadvantages of linking cap-and-trade systems", *Climate Policy*, Vol. 9/4, pp. 358-372, http://dx.doi.org/10.3763/cpol.2009.0626. [31]

Franks, M., O. Edenhofer and K. Lessmann (2015), "Why Finance Ministers Favor Carbon Taxes, Even If They Do Not Take Climate Change into Account", *Environmental and Resource Economics*, pp. 1-28, http://dx.doi.org/10.1007/s10640-015-9982-1. [36]

G-20 (2009), *Leaders' Statement*, https://g20.org/wp-content/uploads/2014/12/Pittsburgh_Declaration_0.pdf. [52]

G7 (2016), *Leaders' Declaration*, http://www.mofa.go.jp/files/000160266.pdf (accessed on 23 April 2018). [55]

Goulder, L. (1995), "Environmental taxation and the double dividend: A reader's guide", *International Tax and Public Finance*, Vol. 2/2, pp. 157-183, http://dx.doi.org/10.1007/BF00877495. [33]

Goulder, L. and A. Schein (2013), "Carbon taxes versus cap and trade: A critical review", *Climate Change Economics*, Vol. 4/3, pp. 1-28, http://dx.doi.org/10.1142/S2010007813500103. [13]

Government of Alberta (2017), *Climate Leadership Plan: Progress Report 2016-2017*, https://open.alberta.ca/dataset/854af86e-309a-4727-90f9-6bba947dc66e/resource/989797fb-b890-4f52-9e91-43938fff566f/download/clp-progress-report-2016-17.pdf (accessed on 22 October 2018). [17]

Government of New Zealand (2018), *Fossil fuel subsidy reform*, https://www.mfat.govt.nz/en/environment/clean-energy-and-fossil-fuels/ (accessed on 23 April 2018). [54]

Helm, C. (2003), "International emissions trading with endogenous allowance choices", *Journal of Public Economics*, Vol. 87/12, pp. 2737-2747, http://dx.doi.org/10.1016/s0047-2727(02)00138-x. [98]

Helm, D., C. Hepburn and G. Ruta (2012), "Trade, climate change, and the political game theory of border carbon adjustments", *Oxford Review of Economic Policy*, Vol. 28/2, pp. 368-394, http://dx.doi.org/10.1093/oxrep/grs013. [112]

Hepburn, C. et al. (2016), "The economics of the EU ETS market stability reserve", *Journal of Environmental Economics and Management*, Vol. 80, pp. 1-5, http://dx.doi.org/10.1016/J.JEEM.2016.09.010. [88]

High-Level Commission on Carbon Prices (2017), *Report of the High-Level Commission on Carbon Prices*, World Bank, Washington DC, https://www.carbonpricingleadership.org/ (accessed on 3 August 2018). [8]

Hirst, D. and M. Keep (2018), "Carbon Price Floor (CPF) and the price support mechanism", No. SN05927, https://researchbriefings.parliament.uk/ResearchBriefing/Summary/SN05927 (accessed on 3 August 2018). [21]

Hood, C. and C. Soo (2017), "Accounting for mitigation targets in Nationally Determined Contributions under the Paris Agreement", *Climate Change Expert Group*, No. 2017(5), http://www.oecd.org/environment/cc/ccxg.htm (accessed on 29 October 2018). [80]

Hufbauer, G. and J. Kim (2009), "The World Trade Organization and Climate Change: Challenges and Options", *Peterson Institute for International Economics Working Paper*, Vol. No. 09-9, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1478677 (accessed on 30 May 2018). [109]

ICAO (2016), *On a board a sustainable future: 2016 Environmental Report*, ICAO, https://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf (accessed on 26 April 2018). [65]

ICAP (2018), *California publishes draft amendments of cap-and-trade regulation*, https://icapcarbonaction.com/en/news-archive/576-california-publishes-draft-amendments-of-cap-and-trade-regulation (accessed on 16 October 2018). [125]

ICAP (2018), *Emissions Trading Worldwide: Status Report 2018*, https://icapcarbonaction.com/en/?option=com_attach&task=download&id=547 (accessed on 1 June 2018). [18]

ICAP (2018), *Fact Sheet: Kazakhstan Emissions Trading Scheme (KAZ ETS)*, https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=46 (accessed on 18 October 2018). [133]

ICAP (2018), *Guide to Linking Emissions Trading Systems*, https://icapcarbonaction.com/en/a-guide-to-linking-emissions-trading-systems. [101]

ICAP (2018), *Netherlands proposes EUR 18 carbon price floor*, https://icapcarbonaction.com/fr/news-archive/491-netherlands-proposes-eur-18-carbon-price-floor (accessed on 3 August 2018). [118]

ICAP (2018), *Ontario revokes cap-and-trade program regulation*, https://icapcarbonaction.com/zh/news-archive/564-ontario-revokes-cap-and-trade-program-regulation (accessed on 16 October 2018). [92]

ICAP (2018), *Swiss ETS*, https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems[]=64 (accessed on 24 October 2018). [121]

ICAP (2016), *Benefits of Emissions Trading*, https://icapcarbonaction.com/en/?option=com_attach&task=download&id=389 (accessed on 24 August 2018). [95]

IEA (2017), *CO2 Emissions from Fuel Combustion 2017*, https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017.pdf (accessed on 26 April 2018). [63]

IETA (2018), *COP24 fails to deliver on mandate for carbon market cooperation*, https://www.ieta.org/page-18192/6961313 (accessed on 18 December 2018). [66]

IETA (2018), *National carbon floor prices and carbon taxation in EU ETS sectors*. [120]

IMO (2018), *Adoption of the initial IMO strategy on reduction of GHG emissions from ships and existing IMO activity related to reducing GHG emissions in the shipping sector*, International Maritime Organization, http://www.imo.org/ (accessed on 3 August 2018). [67]

IPCC (2018), *Global Warming of 1.5 °C: Summary for Policy Makers*, http://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf (accessed on 30 October 2018). [2]

IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, IGES, Japan, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_0_Cover.pdf (accessed on 30 October 2018). [86]

ITF (2018), *Corporate Partnership Board CPB Decarbonising Maritime Transport Pathways to zero-carbon shipping by 2035 Case-Specific Policy Analysis*, OECD, http://www.itf-oecd.org (accessed on 3 August 2018). [68]

ITF (2017), *ITF Transport Outlook 2017*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789282108000-en. [64]

Jaffe, J. and R. Stavins (2008), "Linkage of Tradable Permit Systems in International Climate Policy Architecture", *NBER Working Paper*, Vol. No. 14432, http://dx.doi.org/10.3386/w14432. [100]

Jakob, M. et al. (2016), "Carbon Pricing Revenues Could Close Infrastructure Access Gaps", *World Development*, Vol. 84, pp. 254-265, http://dx.doi.org/10.1016/J.WORLDDEV.2016.03.001. [37]

Kahn, D. (2013), *E.U. market troubles will prevent emissions trade linkage -- Calif. air chief*, https://www.eenews.net/climatewire/2013/04/19/stories/1059979761 (accessed on 24 October 2018). [122]

Keohane, N. (2009), "Cap and Trade, Rehabilitated: Using Tradable Permits to Control U.S. Greenhouse Gases", *Review of Environmental Economics and Policy*, Vol. 3/1, pp. 42-62, http://dx.doi.org/10.1093/reep/ren021. [131]

Keohane, N., A. Petsonk and A. Hanafi (2017), "Toward a club of carbon markets", *Climatic Change*, http://dx.doi.org/10.1007/s10584-015-1506-z. [105]

Klenert, D. and L. Mattauch (2016), "How to make a carbon tax reform progressive: The role of subsistence consumption", *Economics Letters*, Vol. 138, pp. 100-103, http://dx.doi.org/10.1016/J.ECONLET.2015.11.019. [34]

Lazarus, M. et al. (2015), *Options and Issues for Restricted Linking of Emissions Trading Systems*, ICAP, https://icapcarbonaction.com/en/?option=com_attach&task=download&id=279. [124]

MacKay, D. et al. (2015), "Price carbon — I will if you will", *Nature*, Vol. 526/7573, pp. 315-316, http://dx.doi.org/10.1038/526315a. [130]

Mehling, M. and B. Görlach (2016), "Multilateral Linking of Emissions Trading Systems", http://ceepr.mit.edu/files/papers/16-009.pdf (accessed on 25 May 2018). [93]

Mehling, M. and E. Haites (2009), "Mechanisms for linking emissions trading schemes", *Climate Policy*, Vol. 9/2, pp. 169-184, http://dx.doi.org/10.3763/cpol.2008.0524. [90]

Metcalf, G. (1999), "A Distributional Analysis of Green Tax Reforms", *National Tax Journal*, Vol. 52/4, pp. 655-682. [134]

Metcalf, G. and D. Weisbach (2012), "Linking Policies When Tastes Differ: Global Climate Policy in a Heterogeneous World", *Review of Environmental Economics and Policy*, Vol. 6/1, pp. 110-129, http://dx.doi.org/10.1093/reep/rer021. [94]

Meunier, G. and J. Ponssard (2012), "A Sectoral Approach Balancing Global Efficiency and Equity", *Environ Resource Econ*, Vol. 53, pp. 533-552, http://dx.doi.org/10.1007/s10640-012-9575-1. [56]

Moïséi, E. and R. Steenblik (2011), "Trade-Related Measures Based on Processes and Production Methods in the Context of Climate-Change Mitigation", *OECD Trade and Environment Working Papers*, No. 2011/04, http://dx.doi.org/10.1787/18166881. [110]

Monjon, S. and P. Quirion (2011), “Addressing leakage in the EU ETS: Border adjustment or output-based allocation?”, *Ecological Economics*, Vol. 70/11, pp. 1957-1971, http://dx.doi.org/10.1016/J.ECOLECON.2011.04.020. [108]

Morgenstern, R. and W. Pizer (2007), *Reality check: The nature and performance of voluntary environmental programs in the United States, Europe, and Japan*, Resources for the Future. [62]

Murray, B. and N. Rivers (2015), “British Columbia’s revenue-neutral carbon tax: A review of the latest “grand experiment” in environmental policy”, *Energy Policy*, Vol. 86, pp. 674-683, http://dx.doi.org/10.1016/J.ENPOL.2015.08.011. [35]

New Zealand (2015), *Ministerial Declaration on Carbon Markets*, http://www.mfe.govt.nz/news-events/ministerial-declaration-carbon-markets (accessed on 3 August 2018). [82]

Newbery, D., D. Reiner and R. Ritz (2018), “When is a carbon price floor desirable?”, *Cambridge Working Papers in Economics*, No. 1833, http://www.eprg.group.cam.ac.uk. [89]

Newell, R., W. Pizer and D. Raimi (2013), “Carbon Markets 15 Years after Kyoto: Lessons Learned, New Challenges”, *Journal of Economic Perspectives*, Vol. 27/1, pp. 123-146, http://dx.doi.org/10.1257/jep.27.1.123. [74]

Nordhaus, W. (2015), “Climate clubs: Overcoming free-riding in international climate policy”, *American Economic Review*, http://dx.doi.org/10.1257/aer.15000001. [106]

OECD (2019), *General government spending* (indicator), https://dx.doi.org/10.1787/a31cbf4d-en (accessed on 28 March 2019). [45]

OECD (2018), *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264085169-en. [44]

OECD (2018), *Effective Carbon Rates 2018: Pricing Carbon Emissions Through Taxes and Emissions Trading*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264305304-en. [7]

OECD (2018), *Effective carbon rates: Pricing CO2 through Taxes and Emissions Trading Systems.*, OECD Publishing, Paris. [132]

OECD (2018), *OECD Companion to the Inventory of Support Measures for Fossil Fuels 2018*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264286061-en. [50]

OECD (2018), *The Paris Collaborative on Green Budgeting*, OECD Publishing, Paris, http://www.oecd.org/environment/green-budgeting (accessed on 18 December 2018). [47]

OECD (2017), *Investing in Climate, Investing in Growth*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264273528-en. [4]

OECD (2016), *Effective Carbon Rates: Pricing CO2 through Taxes and Emissions Trading Systems*, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264260115-en. [10]

OECD (2016), *Effective Carbon Rates: Pricing CO2 through Taxes and Emissions Trading Systems*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264260115-en. [22]

OECD (2016), *The Economic Consequences of Outdoor Air Pollution*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264257474-en. [40]

OECD (2015), *Aligning Policies for a Low-carbon Economy*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264233294-en. [6]

OECD (2015), *OECD Companion to the Inventory of Support Measures for Fossil Fuels 2015*, OECD Publishing, Paris, https://dx.doi.org/10.1787/9789264239616-en. [48]

OECD (2011), "Interactions Between Emission Trading Systems and Other Overlapping Policy Instruments"*, General Distribution Document, Environment Directorate*, OECD, http://www.oecd.org/env/taxes. [103]

OECD and IEA (2016), *Views on "guidance on cooperative approaches referred to in Article 6, paragraph 2, of the Paris Agreement"*, https://www.oecd.org/env/cc/CCXG-Submission-Art6-final.pdf (accessed on 16 October 2018). [69]

Ostrom, E. (2010), "Polycentric systems for coping with collective action and global environmental change", *Global Environmental Change*, Vol. 20/4, pp. 550-557, http://dx.doi.org/10.1016/J.GLOENVCHA.2010.07.004. [32]

Partnership for Market Readiness (2017), *Supporting carbon pricing policy action: Annual Report 2017*, World Bank, http://www.thepmr.orgpmrsecretariat@worldbank.org. [43]

Prag, A., G. Briner and C. Hood (2012), "Making Markets: Unpacking Design and Governance of Carbon Market Mechanisms"*, OECD/IEA Climate Change Expert Group Papers*, No. 2012/3, OECD Publishing, Paris, https://dx.doi.org/10.1787/5k43nhks65xs-en. [70]

Québec government (2018), *Québec's international action in the fight against climate change*. [42]

Ranson, M. and R. Stavins (2016), "Linkage of greenhouse gas emissions trading systems: learning from experience", *Climate Policy*, Vol. 16/3, pp. 284-300, http://dx.doi.org/10.1080/14693062.2014.997658. [99]

Reinaud, J. (2008), "Issues behind Competitiveness and Carbon Leakage - Focus on Heavy Industry"*, IEA Information Paper*, https://pdfs.semanticscholar.org/9d34/f6b4b6b0923b02f81b5021163606c383ddf8.pdf. [25]

Rentschler, J. and M. Bazilian (2017), "Policy Monitor—Principles for Designing Effective Fossil Fuel Subsidy Reforms", *Review of Environmental Economics and Policy*, Vol. 11/1, pp. 138-155, http://dx.doi.org/10.1093/reep/rew016. [49]

Roy, R. and N. Braathen (2017), "The Rising Cost of Ambient Air Pollution thus far in the 21st Century: Results from the BRIICS and the OECD Countries"*, OECD Environment Working Papers*, No. 124, OECD Publishing, Paris, https://dx.doi.org/10.1787/d1b2b844-en. [39]

Schmidt, J. et al. (2008), “Sector-based approach to the post-2012 climate change policy architecture”, *Climate Policy*, Vol. 8/5, pp. 494-515, http://dx.doi.org/10.3763/cpol.2007.0321. [59]

Schneider, L. (2011), “Perverse incentives under the CDM: an evaluation of HFC-23 destruction projects”, *Climate Policy*, Vol. 11/2, pp. 851-864, http://dx.doi.org/10.3763/cpol.2010.0096. [78]

Schneider, L. (2009), “Assessing the additionality of CDM projects: practical experiences and lessons learned”, *Climate Policy*, Vol. 9/3, pp. 242-254, http://dx.doi.org/10.3763/cpol.2008.0533. [76]

Tinbergen, J. (1952), *On the Theory of Economic Policy*, North-Holland Publishing Company, Amsterdam. [116]

Trotignon, R. (2012), “Combining cap-and-trade with offsets: lessons from the EU-ETS”, *Climate Policy*, Vol. 12/3, pp. 273-287, http://dx.doi.org/10.1080/14693062.2011.637820. [73]

Tuerk, A. et al. (2009), “Linking carbon markets: concepts, case studies and pathways”, *Climate Policy*, Vol. 9/4, pp. 341-357, http://dx.doi.org/10.3763/cpol.2009.0621. [91]

UNFCC (2015), *Adoption of the Paris Agreement*, https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf. [1]

UNFCCC (2018), *CDM Registry*, https://cdm.unfccc.int/Registry/index.html (accessed on 18 December 2018). [83]

UNFCCC (2018), *Clean Development Mechanism (CDM)*, http://cdm.unfccc.int/index.html (accessed on 3 August 2018). [72]

UNFCCC (2017), *Leaders Across the Americas Step up Carbon Pricing*, https://unfccc.int/index.php/news/leaders-across-the-americas-step-up-carbon-pricing (accessed on 22 October 2018). [15]

UNFCCC (2015), *Paris Agreement*, http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (accessed on 10 November 2017). [79]

UNFCCC (1992), *United Nations Framework Convention on Climate Change*, United Nations, New York. [115]

Vaidyula, M. and C. Hood (2018), “Accounting for baseline targets in NDCs: Issues and options for guidance”, *OECD/IEA Climate Change Expert Group Papers* 2, https://www.oecd-ilibrary.org/environment/accounting-for-baseline-targets-in-ndcs_9ae65cc1-en (accessed on 18 December 2018). [81]

Van Dender, K. (2018 forthcoming), “Taxing vehicles, fuel, and road use: what mix for road transport?”, *OECD Taxation Working Papers*. [117]

Walker, J. and E. Ostrom (2003), *Trust and reciprocity : interdisciplinary lessons from experimental research*, Russell Sage Foundation, https://books.google.fr/books?hl=en&lr=&id=cfkWAwAAQBAJ&oi=fnd&pg=PR7&dq=Trust+and+reciprocity:+Interdisciplinary+Lessons+for+Experimental+Research.&ots=WRW2gFn2ne&sig=o0ndlID7Kw0TQC3mYTZ42owP5sg&redir_esc=y#v=onepage&q=Trust%20and%20reciprocity%3A%20Interdisciplinary%20Lessons%20for%20Experimental%20Research.&f=false (accessed on 17 October 2018). [29]

Wara, M. (2007), "Is the global carbon market working?", *Nature*, Vol. 445/7128, pp. 595-596, http://dx.doi.org/10.1038/445595a. [27]

WBCSD (2012), *Sectoral Market Mechanisms: An effective way forward for climate mitigation*, https://www.wbcsdcement.org/index.php/docman-list-public/public-documents/1299-sectoral-market-mechanisms/file (accessed on 26 April 2018). [60]

Weitzman, M. (2017), "Voting on prices vs . voting on quantities in a World Climate Assembly", *Research in Economics*, Vol. 71/2, pp. 199-211, http://dx.doi.org/10.1016/j.rie.2016.10.004. [127]

Weitzman, M. (2017), "Voting on prices vs. voting on quantities in a World Climate Assembly", *Research in Economics*, http://dx.doi.org/10.1016/j.rie.2016.10.004. [114]

Weitzman, M. (2014), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?", *Journal of the Association of Environmental and Resource Economists*, Vol. 1/1/2, pp. 29-49, http://dx.doi.org/10.1086/676039. [126]

Weitzman, M. (2014), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?", *Journal of the Association of Environmental and Resource Economists*, Vol. 1/1/2, pp. 29-49, http://dx.doi.org/10.1086/676039. [128]

Weitzman, M. (2014), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?", *Journal of the Association of Environmental and Resource Economists*, Vol. 1/1/2, pp. 29-49, http://dx.doi.org/10.1086/676039. [129]

Weitzman, M. (2014), "Can Negotiating a Uniform Carbon Price Help to Internalize the Global Warming Externality?", *Journal of the Association of Environmental and Resource Economists*, Vol. 1/1/2, pp. 29-49, http://dx.doi.org/10.1086/676039. [136]

Weitzman, M. and B. Holtsmark (2018), "On the Effects of Linking Voluntary Cap-and-Trade Systems for CO2 Emissions", *NBER WORKING PAPER SERIES*, No. 25001, http://www.nber.org/papers/w25001. [135]

WHO (2018), *Ambient air pollution - a major threat to health and climate*, http://www.who.int/airpollution/ambient/en/ (accessed on 19 October 2018). [38]

World Bank (2016), "Carbon Credits and Additionality Past, Present, and Future", *Partnership for Market Readiness*, No. 13, World Bank, https://openknowledge.worldbank.org/bitstream/handle/10986/24295/K8835.pdf?sequence=2&isAllowed=y. [77]

World Bank and Ecofys (2018), *State and Trends of Carbon Pricing 2018*, Washington, DC: World Bank, http://dx.doi.org/10.1596/978-1-4648-1292-7. [5]

World Bank, Ecofys and Vivid Economics (2017), *State and Trends of Carbon Pricing 2017*, Washington, DC: World Bank, http://dx.doi.org/10.1596/978-1-4648-1218-7. [20]

World Bank, Ecofys and Vivid Economics (2016), *State and Trends of Carbon Pricing 2016*, Washington, DC: World Bank, http://dx.doi.org/10.1596/978-1-4648-1001-5. [19]

Worldsteel (2017), *Steel's contribution to a low carbon future and climate resilient societies*, https://www.worldsteel.org/en/dam/jcr:66fed386-fd0b-485e-aa23-b8a5e7533435/Position_paper_climate_2017.pdf. [57]

Zhang, J. and C. Wang (2011), "Co-benefits and additionality of the clean development mechanism: An empirical analysis", *Journal of Environmental Economics and Management*, Vol. 62/2, pp. 140-154, http://dx.doi.org/10.1016/J.JEEM.2011.03.003. [28]