UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Developing Countries in International Trade Studies

Carbon pricing

A development and trade reality check

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Executive Summary

The scientific evidence draws a clear picture: To limit global warming to 1.5 °C above pre-industrial levels, Green House Gas (GHG) emissions need to peak before 2025 and be reduced by 43 per cent by 2030, while net zero emissions need to be achieved globally in the early 2050s (Intergovernmental Panel on Climate Change (IPCC)). The international climate change legal framework is also clear. It requires all countries to adopt climate change mitigation measures in order to achieve the common objective of limiting the increase in global temperatures to "well below" 2°C but leaves each country free to choose the specific measures and policies to meet their individual emissions reduction targets.

This report focuses on carbon pricing as one policy strand used to tackle global GHG emissions. It gives an overview of implemented and forthcoming domestic and cross-border carbon pricing mechanisms, as well as their implications for GHG emissions, international trade and development. It lays out the characteristics of various approaches, including the potential pitfalls and unintended economic and environmental side effects which need to be addressed for these approaches to work.

Carbon pricing could play a core role in the transition to decarbonized economies.

Climate change has drastic and sizeable impacts on almost all aspects of human life. It imposes considerable costs and disruptive risks on both current and future generations, which are only imperfectly reflected in current market prices.

The main objective of carbon pricing is to increase the price of carbon-emitting activities to reflect the social cost of carbon emissions and the resulting climate change. By changing the prices of carbon-emitting goods and services, carbon pricing has the potential to shift consumption and production away from GHG-intensive activities towards more sustainable alternatives.

The number of countries who have adopted carbon pricing schemes is increasing: In 2022, 46 national/regional and 36 subnational jurisdictions have a price on carbon. Carbon pricing initiatives cover a total of almost 12 gigatonnes of CO2 emissions in 2022, which correspond to 23 per cent of global GHG emissions. Observed median carbon prices are, however, still more than 50 per cent lower than the levels considered necessary to reach the 1.5 °C objective.

Domestic carbon pricing schemes can have a significant impact on international trade.

Carbon pricing is regarded as a cost-effective way to achieve emissions reduction, and one of the two commonly considered policies (direct regulations such as efficiency requirements of electric appliances being the second alternative). In practice, domestic carbon taxes and emissions trading systems (ETS) are the most widely used carbon pricing schemes. However, a reduction in domestic emissions may not result in a reduction of global emissions if trading partners do not adopt similar environmental policies, resulting in domestic production being substituted by more carbon-intensive imports.

This effect could be observed if domestic firms react to the establishment of a domestic carbon scheme by relocating parts of their production to locations applying loose environmental regulations or if their competitiveness is reduced and foreign companies gain market shares. This risk of carbon leakage has increased over time with the evolution of global production chains.

Carbon border adjustment schemes aim to fight the threat of carbon leakage.

In the absence of international coordination on carbon pricing, the implementation of measures at borders may counter negative economic and environmental spillovers. Carbon border adjustment schemes are a special category of carbon pricing schemes and are considered by some to complement domestic ones by targeting imports of carbon-intensive products.

Such carbon border adjustment schemes allow for equivalent carbon pricing for imports and domestic products. Similar to tariffs, carbon border taxes affect domestic and foreign production, trade flows and government revenues. By raising the price of imported goods, they limit competition from goods produced in locations with lower or zero carbon prices and may also affect climate policy implementation in affected exporting economies.

The European Union's Carbon Border Adjustment Mechanism (CBAM) is the first border adjustment scheme to be implemented, and targets select carbon intensive sectors. After a transitional gradual phase-in period, carbon certificates will have to be acquired which correspond to the carbon price that would have been paid to produce the good in the European Union. Results from simulations of the possible effects of the CBAM suggest that the scheme would address leakage and reduce emissions, but also lead to trade diversion: Trade within the European Union is expected to increase while trade flows of trading partners are diverted to other regions. Developing countries total exports in the targeted sectors is expected to decline more than that of developed countries since developed country producers, as a whole, employ less carbon intensive production methods than their developing country counterparts.

Complementary policies to carbon pricing should counteract rising inequality and increase its effectiveness.

Carbon pricing does not affect all agents in an economy equally. For example, it can affect the poorest households to a greater extent if a high share of their income is spent on carbon-intensive goods whose prices will increase following the introduction of carbon pricing. Furthermore, smaller firms could be impacted more severely by carbon pricing schemes as they may not be able to invest in less carbon-intensive technologies and production processes.

Therefore, complementary policies should be envisaged to counter the negative distributional effects of carbon pricing. Financial resources that are generated by carbon pricing schemes could be used to incentivize innovation and investment in low-carbon-intensive activities and alleviate the impact on lower-income households and countries.

Furthermore, existing evidence shows that price incentives are necessary but potentially insufficient measures to promote behavioural changes and reduce global warming. Policies aimed at affecting behaviour therefore need to include information and other features on top of price incentives in order to increase acceptance and support, and thus effectiveness.

Fossil fuel exporting countries face a multitude of challenges that should not be neglected.

Limiting global warming to 1.5 °C above pre-industrial levels would require leaving more than half of today's fossil fuel reserves unextracted by 2050. Countries dependent on exports of hydrocarbons will lose a major source of foreign currency revenues. This concerns established fuel exporters as well as developing and least developed countries, which have only recently discovered fossil fuel resources.

The risk of stranded assets could also lead to the "Green Paradox": The anticipation of the future collapse in the value of fossil fuel reserves may result in increased production and related emissions in the short run, thereby accelerating global warming.

Could carbon pricing play a core role in the transition to decarbonized economies? With coordination among stakeholders and international cooperation it can!

Carbon pricing can be effective when broad economic activities are priced. Coordination between economic actors including consumers and private sector companies as well as between countries is needed.

Given their greater exposure to climate risks, developing and least developed countries may gain significantly from global mitigation efforts in the longer run. In the short run, however, they may have little means to undertake costly emission reductions. Many developing countries are not able to raise the necessary funds domestically to promote the transition towards cleaner technologies and lack the nstitutional capacity to implement carbon pricing schemes such as emissions trading systems.

International cooperation is therefore crucial to globalize efforts to combat global warming. More advanced countries should deliver on their commitments made in the negotiating rounds of the Conference of the Parties (COP) and mobilize climate finance funds for less advanced economies to help them adopt technologies that transition their economies towards lower carbon emissions.

Chapter 1

Introduction

Climate change is usually associated with the climatic consequences of accumulations of greenhouse gases (GHGs) in the atmosphere. Carbon dioxide (CO2) has been the most prominently emitted GHG since information on emissions started being collected. As shown in table 1, it represents about three quarters of global annual GHG emissions. Methane is the second most prominent GHG, accounting for a further 17.5 per cent of global emissions. Nitrous oxides (N2O) and other gases account for the remaining GHG emissions.[1] As to economic sectors, energy production is responsible for the largest share in total GHG emissions (75 per cent) followed by agriculture (13 per cent) and industrial processes (4.5 per cent). While the energy sector emits CO2 (78 per cent of total emissions), agriculture accounts for the largest share of methane (44 per cent of total) and nitrous oxides emissions (75 per cent of total) while industrial processes are the sole emitter of fluorinated gases. The largest economies are also the largest emitters of GHGs. China released about 12.7 Gt of CO2e in 2019, followed by the United States of America which released about 6 Gt of CO2e. India released about 3.4 Gt of CO2e, the Russian Federation 2.5 Gt, Japan 1.2 Gt and Brazil 1.1 Gt . Major oil and natural gases exporters are also among the largest emitters in per capita terms. Qatar emitted about 40.5 tonnes of CO2e per capita in 2019, followed by Bahrain (33 tCO2e/capita), Kuwait (32.5 tCO2e/capita), Turkmenistan (26.5 tCO2e/capita), the United Arab Emirates (25 tCO2e/capita) and Australia (23 tCO2e/capita).[2]

Table 1 Summary of GHG emissions in 2019

Gas	Level in Gigatonnes of CO2e	Share in Total (%)
Carbon dioxide (CO2)	35.51	73.8
Methane (CH4)	8.42	17.5
Nitrous oxides (N2O)	3.00	6.25
Fluorinated gases (F-gas)	1.18	2.45
Total	48.11	100

Source: Author's own elaboration based on World Resources Institute Climate Analysis Indicators Tools (CAIT) data set.

Notes: Total emissions do not include land-use change and forestry emissions (LUCF). CAIT data set includes all sectors and gases, which explains the three-year lag. To emphasize comparability of data across countries, it does not use countries' official inventories reported to the UNFCCC.

The link between GHG emissions and global warming, a major reflection of climate change, has been established by climate models for several decades (e.g. IPCC, 1990; IPCC, 2014; Collins et al., 2013; Ehlert and Zickfeld, 2017; Hare and Meinshausen, 2006; Herrington and Zickfeld, 2014). Emissions reduction is a necessity if global warming is to be contained. GHG emissions accumulate over time in the atmosphere and the overall effect is cumulative on climate change. The effect of past cumulative emissions is already visible (as the planet has warmed by 1 degree on average since pre-industrial levels) and will increase over the next few years. To limit the rise of global temperature to below 1.5 °C above pre-industrial levels, global greenhouse gas emissions must be reduced 45 per cent from 2010 levels by 2030 and zero net emissions should be achieved by 2050 (IPCC, 2022).

Climate change imposes considerable costs and disruptive risks on both current and future generations. It will have drastic and sizeable impacts on almost all aspects of human life. The World Health Organization predicts that between 2030 and 2050 climate change could cause 250,000 additional deaths per annum through malnutrition, malaria, diarrhoea, and heat stress alone (WHO, 2018). It also has immense social and political implications, including social unrest and large-scale conflicts (e.g. Burke, Hsiang and Miguel, 2014; Harrari and La Ferrara, 2018) as well as mass displacement (Rigaud et al., 2018). The impact on the economy is also expected to be substantial (Alvarez and Rossi-Hansberg, 2021). Climate change

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[1] Annex 1 provides CO2 emissions equivalences for GHGs listed in table 1.

[2] See the CAIT country greenhouse gas emissions data set for details at https://www.wri.org/data/cait-climate-data-explorer.

will result in changes in crop yields, loss of land and capital due to sea level rise, capital damages from hurricanes, changes in fisheries catches, labour productivity changes and tourism flows, changes in health care expenditures due to diseases and heat stress, and changes in energy demand for cooling and heating. Currently the costs and risks imposed by climate change are only imperfectly reflected in market prices. Further internalization of these costs is thus needed to overcome this market failure.

In this context, carbon pricing can play a key role in the transition to a decarbonized economy. The purpose of carbon pricing schemes is to account for the price of all carbon-emitting activities (reflecting the social cost of carbon emissions and climate change). By changing the relative prices of goods and services depending on their carbon content, carbon pricing mechanisms will naturally shift consumption and production towards less GHG–intensive activities and reduce GHG emissions.

Carbon pricing is generally presented as a highly cost-effective[3] policy approach to achieve emissions reduction (e.g. Auffhammer et al., 2016; Tietenberg, 1990). However, carbon pricing may generate outcomes at both the domestic and international level that are not necessarily reflected in cost-effectiveness calculations. Domestically, carbon pricing can lead to distributional tensions. Indeed, pricing emissions can harm the poorest segments of the population if a high share of the income of these households is spent on carbon-intensive goods (e.g. Andersson and Atkinson 2020; Fullerton, 2011). Internationally, carbon pricing policies can influence international competitiveness. For example, if production costs increase in countries applying carbon pricing schemes, firms in those countries may suffer from a loss of competitiveness on international markets and their export potential could thus be negatively impacted. Carbon pricing schemes, like any other policy instrument or feature that affects production costs, can have important trade consequences. Moreover, some firms may decide to relocate their production to countries applying loose environmental policies to circumvent increases in production costs. If such relocation occurs along global production chains, trade patterns may be durably impacted.

To avoid competitiveness issues, all countries should impose some kind of carbon pricing scheme to force economic agents to internalize the cost of their GHG emissions. Without proper and effective coordination among countries any effort to curb GHG emissions locally will be in vain and may even result in an increase in GHG emissions globally. Coordination at the international level, however, remains a major challenge despite commitments recently made by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC). Countries with more stringent environmental policies and binding carbon pricing schemes may have to rely on second-best policies, such as carbon border adjustment schemes, to offset the consequences of weak global coordination.

Carbon pricing schemes can generate fiscal revenues and for that reason may prevail over policies that exclusively impose emissions-related restrictions. Revenues from carbon pricing can be used to support decarbonization, especially if budgetary constraints are tight. They can be used to reduce the cost of emissions abatement. They can also be used to ease any income distributional tensions created by carbon pricing. This suggests that carbon pricing should not be the only instrument of a climate policy package aiming at effectively reducing GHG emissions. It should be part of a larger set of public policies designed to monitor and accompanythe transition of firms and households towards a net zero emissions economy. Public resources may be lacking given the considerable financial needs of a globally successful environmental policy. In addition to global coherence of national environmental policies, the involvement of the private sector can be decisive in mobilizing private savings and fostering technological innovation.

Carbon pricing will undoubtedly induce a reduction in demand for hydrocarbons in the coming years. Because of this, countries dependent on exports of hydrocarbons will lose a major source of foreign

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[3] For a given emission reduction, a policy is cost-effective if it achieves this reduction at least cost. A policy is efficient if it maximizes net benefits, or total benefits minus total costs.

currency revenues. If not anticipated, a drastic drop in currency revenues may have dramatic economic effects beyond a change in the countries' trade patterns.

The rest of this report is organized as follows. Chapter 2 presents some background information about carbon pricing respectively from a conceptual, institutional, and practical standpoint. Chapter 3 reviews the various carbon pricing schemes that could be implemented and discusses their respective expected impacts and relative merits. Chapter 4 examines the existing empirical evidence relating to the various carbon pricing schemes. Its major objective is to define a set of impact dimensions that could be considered the most relevant from a policy action standpoint. Chapter 5 reviews non-market-based approaches to carbon pricing. The last chapter explores the various policies to be implemented in this area to mitigate GHG emissions as effectively and efficiently as possible.

Chapter 2

Putting a price on carbon: What is at stake?

This chapter briefly reviews the scope and objectives of carbon pricing from a conceptual point of view. It then discusses the framing of carbon pricing principles at the international level and describes their national counterparts.

2.1 SCOPE AND OBJECTIVES OF CARBON PRICING

Pricing carbon can help internalize the negative externality generated by GHG emissions and obtain a level of GHG emissions that reflects the social cost of carbon (see annex 1). Putting a price on carbon is expected to impose, at least partially, the burden for the damage from GHG emissions on those responsible for them (the polluter-pays principle). The quantities of GHG-intensive activities will therefore be reduced (as their price will increase relative to non-emitting goods and services). The cost of carbon will in general be shared between producers (i.e. emitters) and consumers. The precise distribution of the carbon cost reflects the balancing of market power between these two sets of economic actors as well as some behavioural parameters such as the relative elasticities of product supply and demand. Governments can reduce the GHG content of the services they provide and of the investments they finance. They may also be able to intervene ex post to influence carbon cost distribution (e.g. through broader redistribution policies).

A carbon price can be either explicit or implicit. When it is explicit, the carbon price refers to CO2 emissions directly and is expressed in terms of “per tonne of CO2 or CO2 equivalent (CO2e)” emissions. When it is implicit, the carbon price is expressed in terms of the quantity (i.e in specific form) or value (i.e. in ad valorem form) of the targeted product. Its explicit form would correspond to the ratio between the total amount paid for carbon emissions and the quantity of CO2 emitted to produce the targeted product. For example, taxes imposed on polluting goods such as fuels are often expressed in units of these goods (e.g. per litre of fuel) and not per unit of CO2e emissions. To obtain an explicit carbon price, the amount of the tax paid per litre of fuel would have to be divided by the quantity of CO2 emitted by the combustion of one litre of fuel.

The impact of a carbon price whether explicit or implicit should be the same. It provides an economic signal to emitters who can use it to decide to either transform their activities and lower their emissions, or to continue emitting and pay for their emissions. Consumers may also react to an increase in prices due to the inclusion of the carbon cost by either reducing their consumption or shifting their consumption preferences towards less carbon-intensive goods and services.

Carbon pricing can be implemented via several policy schemes and instruments, shown in table 2. A distinction is usually made between carbon pricing instruments based on market mechanisms (e.g. carbon taxes and permit markets) and carbon pricing instruments based on non-market mechanisms (command-and-control type tools, labels and information, or voluntary initiatives). Carbon tax is usually perceived as being based on a market mechanism as it relies on price adjustment to reduce quantities.[4]

The pervasiveness of price changes due to carbon pricing schemes does not depend either on the type of scheme implemented (i.e. carbon tax or pollution permit market) or on the economic location of the pricing scheme (i.e. more upstream or downstream in the production process as the tax will automatically pass through the supply chain). Several instruments can be implemented at the same time. For governments, the choice of carbon pricing approach should be based on national circumstances and political realities.

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[4] The UNFCCC categorization distinguishes between market-based approaches and non-market-based approaches. In the former case emissions rights or offsets can be exchanged on some dedicated markets and an equilibrium price is defined explicitly. In the latter case, no exchange of emissions rights is expected. Pricing or any quantity-based regulations are pre-determined by some central competent authority.

Table 2 Main carbon pricing schemes and instruments

Mechanism	Instrument	Price
Market	Emissions Trading System (and derivatives)	Explicit
	Offsets	Explicit
	Taxes and tariffs	Implicit/explicit
	Carbon border adjustment tax	Explicit
Non-Market	Emissions cap	Shadow
	Results-based carbon financing	Explicit/Implicit
	Internal pricing	Explicit/Implicit/Shadow
	Standards and other regulations	Implicit
	Labels	Implicit

Source: Author's own elaboration.

2.2 THE INTERNATIONAL INSTITUTIONAL CONTEXT FOR CARBON PRICING

Countries such as Finland, Norway and Denmark introduced a carbon tax or an energy tax related to carbon content during the first half of the 1990s.[5] Carbon pricing became an international concern with the introduction of the flexibility mechanisms under the Kyoto Protocol adopted in December 1997 at the third Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC).[6] It took almost four decades (see box 1) for countries to design a common plan in response to climate change, and there are still significantly important pending issues relating to its application and implementation.

Box 1 Global response to climate change: some milestone

Creation of the Club of Rome in 1968 and publication of its first report (the Meadows report: "Limits to growth") in 1972

1979: First World Climate Conference (World Meteorological Organization – WMO)
"The conference noted that there was an additional issue of special importance: the problem of possible human influence on climate." (In foreword by D. A. Davies, WMO Secretary-General).

1988: the WMO and United Nations Environment Programme (UNEP) establish the Intergovernmental Panel on Climate Change (IPCC).

1990: Second World Climate Conference
The IPCC releases the first assessment report saying, "emissions resulting from human activities are substantially increasing the atmospheric concentrations of greenhouse gases", leading to calls for a global treaty.

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[5] As of 2022, 36 carbon tax programmes have been implemented across the world. Past, existing, and planned carbon tax regimes are summarized in World Bank (2022).

[6] The Convention counts 197 Parties and is the parent treaty of the 2015 Paris Agreement and of the 1997 Kyoto Protocol. The UNFCCC secretariat (UN Climate Change) is the United Nations entity in charge of supporting the global response to the threat of climate change.

1992: the text of the United Nations Framework Convention on Climate Change (UNFCCC) is adopted and opens for signature at the Earth Summit in Rio. Call for global action to curb greenhouse gas emissions and adapt to climate change.

1994: The UNFCC enters into force
Countries that sign the treaty are known as "Parties" and meet annually at the Conference of the Parties (COP) to negotiate multilateral responses to climate change (first COP held in 1995 in Berlin).

1997: COP 3 – adoption of the Kyoto Protocol (KP)
World's first greenhouse gas emissions-reduction treaty. It operationalizes the UNFCCC by committing industrialized countries and economies in transition to limit and reduce GHG emissions in accordance with agreed individual targets. The Convention itself only asks those countries to adopt policies and measures on mitigation and to report periodically.

2001: COP 7 – Marrakesh Accords setting the stage for ratification of the Kyoto Protocol
Formalization of agreement on operational rules for three flexibility mechanisms: International Emissions Trading, the Clean Development Mechanism and Joint Implementation along with a compliance regime and accounting procedures.

2005: EU Emissions Trading Scheme launches + ratification of the Kyoto Protocol

2006: the Clean Development Mechanism (CDM) opens for business

2008: Joint Implementation Mechanism (JI) starts

2010: COP 16 – Cancun Agreements
Comprehensive package by governments to assist developing nations in dealing with climate change: the Green Climate Fund, the Technology Mechanism and the Cancun Adaptation Framework are established.

2015: COP 21 – Paris Agreement adopted
195 nations agreed to combat climate change and act and invest towards a low-carbon, resilient and sustainable future. For the first time an agreement brings all nations into a common cause based on their historic, current, and future responsibilities. Paragraph 136 of the first COP 21 Decision (Adoption of the Paris Agreement) insists on the importance of providing incentives for emissions-reduction activities, including tools such as domestic policies and carbon pricing.

2021: COP 26
Parties to the Kyoto Protocol reaffirmed their commitment to define emissions-reduction targets, so that the rise in the global average temperature can be limited to 1.5 °C rather than 2 °C as agreed during COP 21. Nations reaffirmed their commitment to support developing countries in achieving adaptation by transferring 100 billion dollars annually.

2.2.1 From Kyoto to Paris

The Kyoto Protocol committed industrialized country signatories (so-called "Annex I" countries) to collectively reduce their GHG emissions by at least 5.2 per cent below 1990 levels on average over 2008–2012. Parties had their targets expressed as levels of allowed emissions, which were subsequently turned into Assigned Amount Units (AAUs). The AAUs – each representing a tonne of CO2-equivalent – could then be traded between Parties to satisfy compliance under the Kyoto commitment periods. Annex I countries could fulfil their commitments through domestic actions or the use of three flexibility mechanisms: International Emissions Trading (IET), the Clean Development Mechanism (CDM) and Joint Implementation (JI).

The amendment adopted in Doha, Qatar, in December 2012 provided a basis for the three Kyoto mechanisms to continue for the 2013–2020 period. The IET, JI and CDM were of significant relevance in the creation of cross-boundary carbon markets. The JI and CDM enabled the creation of units linked to actual emissions-reduction efforts that could be used for compliance under the Kyoto Protocol. The combination of these mechanisms was expected to allow a global carbon market to develop, either through direct trade of the units created by the mechanisms, or by creating national and/or regional emissions trading systems.

Paragraph 137 of the first COP 21 Decision (Adoption of the Paris Agreement)[7] specifically includes carbon pricing as an incentive to reduce emissions. Several plans submitted to the UNFCCC recognize the key role of carbon pricing, with about one hundred countries planning or considering carbon pricing mechanisms in their intended national action plans.

Article 6 of the Paris Agreement further defines a framework to facilitate international recognition of cooperative carbon pricing approaches. Article 13 established an enhanced transparency framework (ETF). The framework, which will start in 2024, promotes transparency of reporting on actions taken and progress made in climate change mitigation, adaptation measures and support provided to or received from other parties. The framework also defines international procedures for the review of the reports submitted by countries.

The Paris Agreement imposes a 5- year cycle of increasingly ambitious climate action to be carried out by countries. Countries were expected to submit their climate action plans, defined as nationally determined contributions (NDCs), by 2020. NDCs must define in detail actions taken at the country level to reduce GHG emissions to reach the objectives of the Paris Agreement.

To better frame the efforts towards the long-term goal, article 4, paragraph 19 of the Paris Agreement invited Parties to formulate and communicate, also by 2020, long-term low GHG emission development strategies (LT-LEDS). LT-LEDS help provide long-term perspectives to the NDCs, taking into consideration their common but differentiated responsibilities and respective capabilities. However, unlike NDCs, they are not mandatory. As of March 2022, 50 countries had submitted their LT-LEDS. The list includes all major CO2 emitters.[8]

The Paris Agreement represented a strong signal at both institutional and political level for scaling-up efforts not only to mitigate the effects of climate change but also to adapt to it. The Paris Agreement also resulted in a commitment to make national financial investment and international development assistance consistent with low greenhouse gas emissions objectives and climate resilient development strategies.

2.2.2 The COP 26 outcomes

At COP 26, held in Glasgow in November 2021, Parties to the Kyoto Protocol reaffirmed their commitment to set emissions-reduction targets, to limit the rise in the global average temperature to 1.5 °C rather than 2 °C as agreed during COP 21.

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[7] The full text of the Paris Agreement, adopted on December 12, 2015, is available at: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

[8] Note that the EU and separately, 17 of its members appear in the list. Details are available at https://unfccc.int/process/the-paris-agreement/long-term-strategies.

The Glasgow Climate Pact contains a series of agreed items. Existing rules have been extended to comprehensively lay out how countries are responsible for delivering on their climate action promises and self-set targets under NDCs to be submitted by COP 27. The ETF established by the Paris Agreement was reaffirmed and agreement was also reached on operational guidance on reporting and review under the transparency system. Parties adopted the reporting tables and formats, outlines for the biennial transparency report and the technical review report, as well as the training programme for technical review experts. Other important and unprecedented decisions were taken such as the phasing-out of unabated coal power and the removal of inefficient fossil fuel subsidies. Nations reaffirmed their commitment to support developing countries in achieving adaptation by transferring 100 billion dollars annually from developed to developing countries. Finally, market mechanisms and non-market approaches to carbon pricing included in the Paris Agreement's set of rules were further developed.

2.3 CARBON PRICING IN PRACTICE

The number of countries implementing some kind of carbon pricing scheme is increasing.[9] Regulatory bodies in two major transport sectors have also taken initiatives at the international level to contain GHG emissions.

2.3.1 Regional, national, and subnational carbon pricing schemes

About 46 national or regional, and 36 subnational jurisdictions put a price on carbon in 2022. The implemented carbon pricing initiatives cover a total of 11.83 gigatonnes of CO2e, corresponding to 23.11 per cent of global GHG emissions. Nine developing countries have implemented a carbon pricing scheme so far and cover 6.35 gigatonnes of CO2e, corresponding to 12.42 per cent of global GHG emissions.[10]

As reported in table 3, of the 68 carbon pricing schemes implemented in 2022, 36 are taxes and 32 are trading systems. Finland implemented the first carbon tax in 1990. The European Union put in place the first trading mechanism, the EU ETS, in 2005.[11]

While carbon taxes are predominantly implemented at the national and regional levels, an emissions trading system (ETS) is the preferred carbon pricing instrument at the subnational level. Two thirds of forthcoming initiatives, whether already scheduled or under consideration, at the national or subnational levels are trading systems.

As discussed previously, carbon offsets giving rise to emission credits is also one of the possible carbon pricing approaches being considered by policymakers. In addition to international and independent crediting programmes, 12 were active at the national and 13 at the subnational level in 2022. A further six programmes are under consideration.

Several European countries participating in the EU ETS have also implemented carbon tax schemes. For example, Nordic countries introduced such schemes at the beginning of the 1990s with a clear early objective of reducing GHG emissions. They have been ambitious schemes since their introduction, covering between one third and two thirds of total jurisdictional emissions. Initiatives in other European countries are much more recent and in general less ambitious in terms of total GHG coverage than the original initiatives in Nordic countries.

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[9] See The World Bank Carbon Pricing Dashboard database for detailed information https://carbonpricingdashboard.worldbank.org/.

[10] China alone covers 4.50 gigatonnes of CO2e (i.e. 8.79 per cent of global GHG emissions).

[11] See FSR Climate (2020) for an historical perspective and technical description of the EU ETS.

Table 3 Regional, national and subnational carbon pricing and crediting initiatives, as of 2022

Instrument	Jurisdictional level	Implemented	Scheduled	Under consideration	GHG emissions (GtCO2e)	Share of total emissions
Carbon Tax	National, Regional	28	1	3	2.84	5.54%
	Subnational	8		4	0.06	0.12%
ETS	National, Regional	10	1	10	7.56	14.76%
	Subnational	22	1	6	1.4	2.74%
Carbon Crediting	National, Regional	12		3		
	Subnational	13		3		

Source: Author's own elaboration based on the World Bank Carbon Pricing Dashboard data set.

Note: Regional should be understood as supranational. Data on International (CDM and JI) and independent (ACR, CAR, Gold Standard, VCR) crediting mechanisms are not included.

Carbon tax schemes often differ across countries. For example, some schemes may not apply to all GHGs, and sector coverage may also vary. A common feature, however, is the search for a high degree of complementarity, or minimal de facto or de jure overlap, with the EU ETS.[12] For instance, Norway exempts operators covered by the EU ETS from the carbon tax, except for offshore oil production activities. In the case of the Spanish carbon tax, it impinges on fluorinated GHG emissions which are not covered by the EU ETS. In Portugal, the carbon tax rate is tied to the average EU ETS price in the preceding year.

The European Union Carbon Border Adjustment Mechanism (CBAM) is the first border adjustment scheme to be implemented (box 2). It is due to start in January 2023. Carbon border adjustment schemes are distinct from domestic carbon taxes as their jurisdiction of reference in terms of GHG emissions reductions is not the domestic economy.

Box 2 The European Union carbon border adjustment mechanism (CBAM)

As stated in the Proposal for a Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism "The initiative for a carbon border adjustment mechanism ('CBAM') is a part of the 'Fit for 55 Package'." Moreover, "the CBAM is a climate measure which should prevent the risk of carbon leakage and support the Union's increased ambition on climate mitigation, while ensuring WTO compatibility."[13]

Objectives and principles

The CBAM aims to reduce the risk of carbon leakage by ensuring equivalent carbon pricing for imports and domestic products. The CBAM will be progressively phased in and free allowances in sectors covered by the CBAM phased out.

To guarantee compatibility with World Trade Organization (WTO) rules, the gradual transition from the current system of free allowances to the CBAM should in no case result in more favourable treatment for goods produced within the European Union compared to goods imported from third countries.

The CBAM seeks to complement existing mechanisms (i.e. EU ETS and financial compensatory measures) to address the risk of carbon leakage in the most exposed sectors or subsectors.

A transitional and gradual phase-in period running from 2023 until 2025 is considered to reduce the risk of disruptive impacts on trade.

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[12] This is to avoid the type of counterproductive dynamics described below in section 3.3.

[13] See the Draft Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism COM/ (2021) / 564 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0564

Scope

The GHG emissions to be regulated by the CBAM should correspond to carbon dioxide as well as, where relevant, nitrous oxide and perfluorocarbons.

The CBAM should apply to goods imported from third countries except from those where their production has already been subject to the EU ETS, i.e. for the time being the European Free Trade Association (EFTA) member States: Iceland, Liechtenstein, Norway and Switzerland.

The CBAM aims to price GHG emissions embedded in the sectors currently covered by the EU ETS, namely: cement, aluminium, iron and steel, fertilizers, and electricity. Note, that while the EU ETS applies to certain production processes and activities, the CBAM will target the corresponding imports of goods.

Mechanism

Both the EU ETS and the CBAM share the objective of pricing GHGs emissions in certain specific sectors. However, while the EU ETS sets an absolute cap on GHGs emissions and allows tradability of allowances, the CBAM establishes no quantitative limits to imports, to ensure that trade is not restricted.

The CBAM will initially apply to direct emissions of GHGs from the production of goods up to the time of import into the European Union. After the end of the transition period and conditional on reassessment results, the CBAM will also apply to indirect emissions, mirroring the scope of the EU ETS.

The CBAM is expected to closely reflect the EU ETS price. The price of CBAM certificates required to import goods covered by the scheme will be derived from weekly averages of auction prices observed in the EU ETS market. The European Commission will be in principle responsible for the calculation and publication of that average price.

CBAM certificates will be obtained on the basis of a declarative system. The CBAM declarant submits an annual declaration of the emissions embedded in the goods imported and the corresponding number of certificates to be surrendered at a given date (as currently defined the date should be 31 May of each year). Embedded emissions are calculated according to precise formulas detailed in the annex of the CBAM official regulatory text.

Member States will sell CBAM certificates to authorized CBAM declarants established in their State. CBAM certificates will be sold on a common central platform managed by the European Commission. The certificates will be valid for a period of two years from the date of purchase. The authorized CBAM declarant should be allowed to re-sell a portion of the certificates bought in excess to its member State of origin. A penalty payment will be imposed if a CBAM declarant fails to surrender a number of CBAM certificates sufficient to cover the emissions embedded in goods it imported.

International cooperation

The Council of the European Union recognizes that "as the CBAM aims to encourage cleaner production processes, the EU stands ready to work with low and middle-income countries towards the de-carbonisation of their manufacturing industries."[14] International development aid and cooperation are part of the external dimension of the European Green Deal and in line with its international obligations under the Paris Agreement. Support to low- and middle-income countries, with a special attention to least developed countries (LDCs), will also take the form of specific technical assistance to help these countries adapt to the new obligations established by the CBAM.

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[14] See the Draft Regulation of the European Parliament and of the Council establishing a carbon border adjustment mechanism, COM/ (2021) / 564 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0564.

2.3.2 International sectoral carbon pricing initiatives

International initiatives have been largely confined to the transport sector.

In October 2016, member States of the International Civil Aviation Organization (ICAO) adopted the first global sectoral carbon pricing initiative, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Two years later the ICAO's council defined the set of rules guiding the initiative. Known as the Standards and Recommended Practices (SARPs), this set of rules constitutes a major step towards ICAO's goal of capping net emissions from international aviation at 2020 levels for the years 2021-2035.[15] Additional emissions above these levels need to be offset.[16] Starting on 1 January 2019, all airlines flying international routes were required to monitor, report, and verify their CO2 emissions. Since 1 January 2021, they must meet the emissions cap imposed by CORSIA by reducing their own emissions, by burning fuels emitting less CO2 (on a life cycle basis), or by investing in emissions reductions in other sectors.

In its Initial Greenhouse Gas Strategy (IMO 2018), the International Maritime Organization (IMO) adopted mandatory measures to reduce emissions of greenhouse gases from international shipping, under the pollution prevention treaty (MARPOL) and based on the Energy Efficiency Design Index (EEDI), mandatory for new ships, and the Ship Energy Efficiency Management Plan (SEEMP). The evolution of carbon intensity of international shipping should be aligned with reductions of CO2 emissions per transport mode, at an average across international shipping of at least 40 per cent by 2030, and 70 per cent by 2050 as compared to 2008 levels. In addition, overall GHG emissions from international shipping are expected to be reduced by at least 50 per cent by 2050, again compared to 2008 levels. Although these targets do not necessarily entail a carbon pricing scheme, their implementation may be facilitated by the inclusion of the sector in an emissions trading scheme (ETS). This option has been put forward for instance by the European Union in the context of its Green Deal.[17] The inclusion of maritime transport in an ETS is considered as part of a policy package by the European Union to address various aspects of the decarbonization of the sector such as supply of alternative fuels and infrastructure.[18]

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[15] A first voluntary phase runs from 2021-2026. Participation will become mandatory during the years 2027-2035 except for least emitting states. More details are available online: https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx.

[16] CORSIA has the potential to generate demand for carbon assets of around 2.5 GtCO2e between 2021 and 2035. https://www.edf.org/climate/icaos-market-based-measure.

[17] Available online at https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

[18] See Wissner et al. (2021) for a critical assessment.


CO2
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CO2
CO2

Chapter 3

Market-based approaches to carbon pricing: Theoretical assessment

This chapter presents a theoretical assessment of the effects of the two major carbon pricing instruments based on market mechanisms: carbon taxes and emissions trading. Domestic carbon taxes and emissions trading are both expected to negatively affect economic activity. Importantly, a negative impact on production is necessarily associated with a reduction in GHG emissions, which remains the main objective of carbon pricing. This trade-off between economic activity and environmental conditions would result in an increase in domestic welfare only once the true social cost of carbon is considered. However, carbon pricing may not affect all agents in an economy equally. Moreover, in a multi-country context, a reduction in domestic emissions may not result in a reduction in global emissions if some countries do not adopt or adopt only loose environmental policies. Complementary policies should be envisaged. At the domestic level, distributional schemes can be implemented, and financial support provided to firms to reduce their abatement costs. At the international level, if coordination among countries cannot be achieved, the implementation of measures at the border may help contain negative spillovers whether economic or environmental.

3.1 CARBON TAXES

Two different but complementary types of carbon tax are considered. The first is a carbon tax imposed on domestic producers. The second is a tax imposed on the carbon content of imports. The latter would be implemented to counter the effect the former may have on production location. Pairing the two taxes would be effective in reducing global emissions as long as carbon intensity is lower in the country imposing the two taxes.

3.1.1 Domestic carbon tax

An excise tax on CO2 emissions, and more generally on GHGs, also called a Pigouvian tax, can be either explicit or implicit.[19] If explicit, it is a proper carbon/emissions tax based on the quantity of GHGs or their CO2 equivalent emitted during the production process of goods (or services). It defines a carbon price by applying an explicit tax rate on GHG emissions or on the carbon content of fossil fuels burned during the production process. An implicit tax would correspond to the levy of a duty on goods or services that are generally CO2/GHGs-intensive such as petrol or any GHG-emitting energy source.

In a deterministic environment, a carbon tax can achieve Pareto optimal outcomes. Figure 1 illustrates this result. It is a common representation of the way to obtain the optimal carbon price that assembles the social cost of carbon (SCC) with a measure of abatement cost. For ease of interpretation, all curves are kept linear even though this may not be necessarily the case.[20] The MDC curve represents the marginal damage to society of GHG emissions. It is a representation of the SCC for all possible emission level.[21] The MDC curve is upward sloping to reflect the fact that the negative impact of emissions increases with their level. As discussed previously, this would be consistent with both current and cumulative emissions impacting climate with higher effects for higher levels of accumulated emissions. The MAC curve is usually defined as the "marginal abatement curve" and represents the cost for the economy to reduce emissions by one more unit. For each emission level E it gives the cost for the economy to reduce emissions from E_0

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[19] Whether explicit or implicit, the tax can be ad valorem (paid by percentage of the good unit price) or specific (cost charged by unit).

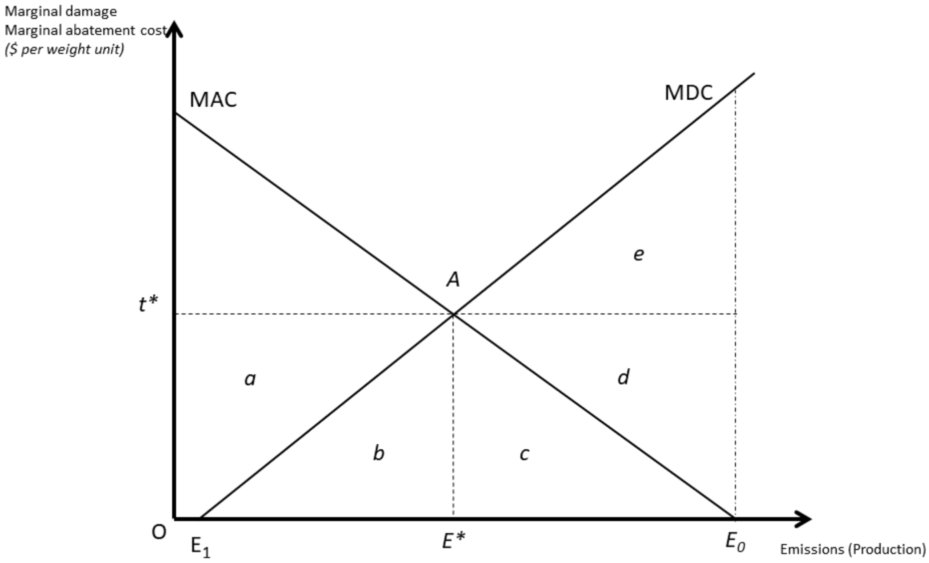
[20] See for instance Keilbach (1995) for an early empirical estimation.

[21] In practice, the determination of an optimal carbon price involves the use of complex assessment models called integrated assessment models (IAMs) that capture feedbacks between the economy and the climate. Two major strands in the literature have emerged. One supports strong discounting (e.g. Nordhaus, 2017) and rather weak SCC (around US$ 40-60 per tonne). The other would favor the inclusion of a larger set of elements in the damage assessment (e.g. Stern and Stiglitz et al. ,2017) but would also apply a lower discount rate (the resulting SCC could be as high US$ 300). van der Ploeg (2020) provides a detailed discussion about the central role played by the adopted discounting approach in framing climate policy.

to E (either through change in production technology or reduction in production/consumption). A change in abatement technology (e.g. a decreasing price of solar panel or any other green technology) would translate in a flatter curve and lower abatement cost.

In the absence of policy intervention, the economy represented would end up emitting levels of GHG (i.e. E_0) that are above the optimal emissions level from a social point of view (i.e. E*). The introduction of the carbon tax t* would set the level of GHG emissions at its optimal. If the firm is emitting more than E*, it can decrease its costs by decreasing its emissions towards E* as the cost of doing so (the abatement cost) is lower than paying the tax for this level of emissions. Figure 1 shows that decreasing emissions from E_0 to E* induces a cost to the firm equivalent to area *c*, while continuing to emit E_0 would induce a cost represented by the area *c* plus *d*. Therefore, reducing emissions is an optimal strategy for the firm when facing a carbon tax *t**. Benefits of the carbon tax are thus represented by area *d* plus *e* plus *c* which represents the amount of social damage reduced. The area corresponding to triangles *a* plus *b* represents the total amount of taxes collected by the imposing authority.

Figure 1 Carbon tax and emissions



Source: Author's elaboration based on Baumol and Oates (1988).

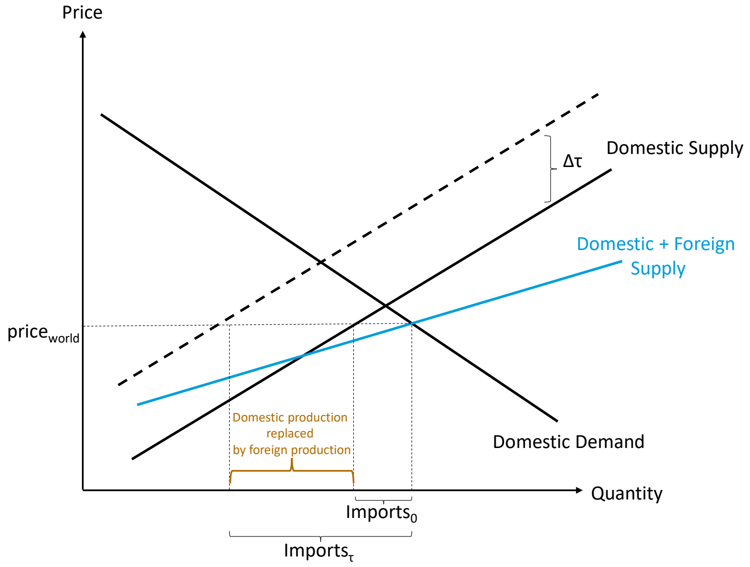
The use of carbon tax revenue can play a key role in an economy's decarbonization strategy. Governments can decide to allocate it to specific public or private carbon-reduction initiatives, possibly promoting emissions-reduction innovation. Emissions E* could be characterized by a lower level of output with respect to the policy-free equilibrium. Firms' profitability is expected to fall if they do not react to the imposition of the tax by introducing some technical or technological improvements. In illustration of this point, the curve MAC could be reinterpreted as an emissions' marginal product curve. The area below would thus reflect total production or at least a proxy of it. Area *c* would then reflect the fall in total production due to the carbon tax imposition. If firms rationalize and optimize their production in reaction to the carbon tax, the curve BB would be affected (rotation counterclockwise around point E_0) and both its intercept to the origin and its slope could change. Consequently, the level of emissions observed could be lower than the originally optimal level. Moreover, it can be easily shown that the fall in production would be lower compared to the fall obtained in the original case. In other words, if firms are incentivized to develop and adopt greener productive technology, the trade-off between production and environmental conditions weakens.

Governments can also use the revenue from carbon taxation to offset the negative impact of taxes on prices paid by consumers. For instance, since carbon taxes are in general found to be regressive, lump-sum transfers covered by the tax revenue could revert their relative impact on the various income groups.[22]

Figure 1 shows that the imposition of a carbon tax may lead to a decrease in domestic production. If domestic and foreign goods are close substitutes, this may result in an increase in imports. If imports are more carbon intensive than domestic products, local emissions could decrease but the gap between national inventories and carbon footprints would increase. The substitution of domestic production by more carbon-intensive imports would then dampen the effect of carbon pricing on global emissions. The global level of emissions may increase, and domestic carbon taxes may thus fail to be cost-efficient once total emissions are considered.

This effect may also be observed if domestic firms react to the establishment of a domestic carbon tax by relocating part of their production to locations with looser environmental policies and/or more carbon-intensive productive technologies. When emissions are restricted domestically, or the price of carbon increases compared to the one prevailing abroad, firms are incentivized to relocate production to other countries either to avoid abatement costs due to regulations or to pay lower carbon prices. This is often referred to as carbon leakage. Such incentives may have been exacerbated by the fragmentation of production processes and the quasi-systemic implementation of global production chains deployed over several countries and continents. If relocation occurs in developing countries the latter may become pollution havens (e.g. Copeland, 2008).

Figure 2 Carbon pricing and leakage: the production perspective



Source: Based on Pethig (1976) and Naegele and Zaklan (2019).

Figure 2 illustrates the full leakage/pollution haven case. With no climate policy in place, total supply to the domestic market is associated with a level of imports represented by $imports_0$. If a carbon price is imposed on domestic producers, the domestic supply shifts to the left (dashed curve). Assuming that the world price remains at $price_{world}$, which implies that domestic demand remains unchanged, imports would increase to meet the original demand level. The increase in imports corresponds precisely to the fall in domestic production. Leakage would be complete from a production point of view. If the carbon intensity

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[22] See Metcaf (2021) for a general discussion.

of production is the same everywhere, then there would be full leakage from an emissions point of view as well. However, with differences in carbon intensity of production, full leakage in emissions terms may not necessarily correspond to full leakage in production terms.[23] In all circumstances the emissions balance related to transport would also have to be considered.

Indirect leakage should also be accounted for when assessing the impact of carbon pricing on emissions. Felder and Rutherford (1993) argue that if carbon pricing depresses domestic demand for fossil fuels, it could also depress their price on international markets if the domestic market is large (the European market for example). Lower prices on international markets may lead to higher consumption of fossil fuels in non-constrained countries, hence higher global GHG emissions. Added to this negative emissions outcome is the possibility that firms, by relocating production abroad, inevitably reduce the number of people they employ . Downward pressure on wages may also occur, with potentially harmful effects on global demand if displacement is large enough. This could help explain the relatively limited scope in established carbon pricing schemes.

3.1.2 Carbon border tax

A carbon border (adjustment) tax is a particular type of carbon tax.[24] It is a duty on imports based in principle on the amount of carbon emissions resulting from the production of the imported product. In most cases, the tax is imposed on imports which have not been carbon-taxed at source, but which would have been had they been produced domestically. As discussed below, the imposition of a tax at the border is only desirable from a welfare point of view in cases where a gap exists between environmental policies applied domestically and those applied abroad.

As a carbon price, a carbon border tax can affect GHG emissions in the imports source country in line with domestic carbon regulation. However, as a trade-related measure, a carbon border tax is similar to a tariff in that it affects production, both domestically and abroad, trade flows and government revenues.

A major motivation for using such a border tax is to reduce carbon leakage, which is the relocation of production to countries with less constraining climate policies, giving rise to pollution havens and undermining global climate objectives. However, by raising the price of imported goods, a carbon adjustment tax also acts as a price equalizer and de facto limits competition from goods produced in locations with lower or zero carbon prices. A carbon border tax may also affect climate policy implementation in those economies which are likely to be directly impacted by the measure.

Figure 3 shows the basic graphical analysis of a tariff in the case of a large importing country. This is a partial equilibrium representation, which only considers sector-specific effects and inter-industry trade. With free trade the original equilibrium is characterized by domestic demand D_0, domestic production S_0, imports M_0 and price p_0.

The impact of a domestic carbon tax implemented in the importing country only can be analysed. As a result of the domestic tax, the domestic supply curve (S_d) shifts up (S'_d). The import demand locus also shifts up. Equilibrium in the international market moves from A_0 to A_1. The carbon tax equilibrium is characterized by lower domestic supply, lower domestic demand (D_1), higher imports, and a higher equilibrium price (p1). Some domestic production has been replaced by foreign production.

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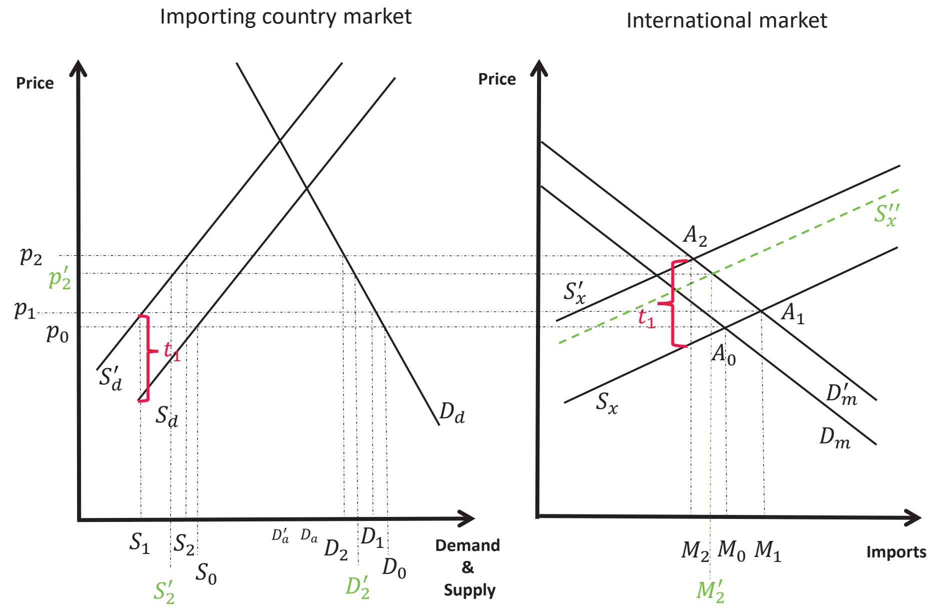
[23] See Sato and Burke (2021) blog post available at https://www.lse.ac.uk/granthaminstitute/news/what-is-carbon-leakage-clarifying-misconceptions-for-a-better-mitigation-effort/.

[24] As mentioned in chapter 2, the European Union decided to put in place a Carbon Border Adjustment Mechanism starting in 2023 (box 2).

Extending the interpretation of the results, we could associate the replacement of domestic by foreign production with leakage. The increase in domestic price is lower than the domestic tax. Relative variations in prices and quantities are driven by existing supply and demand conditions, reflected by slopes and position in the quantity-price space, prevailing in the domestic and in foreign markets.

Based on a simple partial equilibrium two-country theoretical model, consistent with the framework underlying figure 3, Gros (2009) determines the domestic carbon price that is optimal from a global welfare point of view. For given carbon intensities of production in the two countries, the optimal rate is equal to the environmental distortion generated domestically minus a fraction of the distortion generated in the foreign country. The higher the distortion in the foreign country, which is the higher the carbon intensity of foreign production, the smaller the desirability of taxing carbon domestically because of the induced leakage. If the carbon intensity of production is higher in the foreign country, global welfare is negatively affected. From a global welfare point of view subsidizing the domestic production would be preferable to a tax. Still from a global welfare point of view, a higher carbon price abroad would instead justify a higher domestic carbon price.

Figure 3 Carbon border tax



Source: Author's elaboration based on Feenstra and Taylor (2021).

The imposition of a carbon border tax equivalent to the domestic carbon tax would further affect equilibrium characteristics. The policy would shift the export supply curve by the amount of the tax. As a result, the level of imports decreases $(D_2 - S_2)$, and this could be interpreted as a containment of leakage. Due to the existence of elastic supply and demand curves in the domestic and foreign m-arkets, repercussion of the tax on the equilibrium price can only be partial (i.e. the pass-through to consumer is always incomplete). Equilibrium with both carbon taxes corresponds to point A_2 in the international market. Imports fall compared to the previous situation in which the carbon tax only applied to domestic production $(M_2 < M_1)$, domestic price $(p_2 > p_1)$ and production increase $(S_2 > S_1)$, and domestic demand falls $(D_2 < D_1)$. The analysis can be extended to foreign consumption and production. Because of the carbon border tax the price abroad would fall. Consequently, consumption abroad increases and production decreases. In most situations, the rise in consumption abroad is less than proportional to the fall in domestic consumption, with the result that there is a drop in total consumption and hence in total production and emissions.

Gros (2009) computes the welfare effects of the introduction of a border tax on the CO2 content of imported goods in a country which has already established a domestic carbon tax. A higher domestic price of carbon justifies the imposition of a carbon import tax from a welfare point of view. It would help internalize the negative externality generated by unregulated or loosely regulated foreign production. The carbon import tariff is found to increase both the welfare of the importing country and global welfare. Because of the positive impact a carbon border tax would have on foreign consumption, its optimal level from a global point of view is equal to a fraction of the domestic carbon price. However, the optimal carbon border tax rate increases with the carbon intensity of foreign production. The positive terms of trade effect for the importing country, whenever it is large enough to influence international prices, drives welfare results. The terms of trade effect corresponds to an extraction of rent by the importing country from producers abroad even though domestic producers would still be at a "competitive disadvantage" relative to foreign producers if an optimal border carbon tax is imposed.[25]

Figure 3 also shows the effects of implementing a domestic carbon tax in the exporting country, equivalent to the carbon tax applied by the importing countries on domestic production. In this case, imports would not be taxed. The effects on the international market are represented by the S_x'' locus. Assuming that the price repercussion is not complete in the foreign country market, the upward shift of the export supply curve is smaller than that observed in the carbon border tax case. With respect to a carbon border tax, imports ($D_2' - S_2'$)and domestic consumption (D_2') would be higher, price (p_2')and domestic production (S_2') lower.

Gros (2009) also investigates the welfare effects of a carbon border tax when a carbon pricing scheme is implemented by both the importing and exporting countries. If both countries have carbon pricing that maximizes net social benefits, the optimal carbon border tax rate is equal to zero. However, global welfare could increase with the imposition of a carbon border tax even if both countries apply the same domestic price of carbon, but the foreign country has a higher carbon intensity of production. The optimal rate would be equal to a fraction of the difference between the gap between the externality and the domestic carbon tax in the importing country and the same gap in the exporting country. A higher relative carbon intensity of production abroad increases the relative gap and would again justify a higher rate for the carbon border tax, as in the previously reviewed case of no carbon pricing abroad.

Assuming that there is a direct link between production and emissions, and that no technological improvement is introduced, the relative efficiency of each policy configuration in terms of emissions depends on the relative emission intensity of domestic and foreign production. For instance, if domestic production is replaced by more emission intensive foreign production because of the implementation of a domestic carbon tax, then total emissions are expected to rise above their initial level even though they fall drastically from a domestic standpoint. The reverse would be true if carbon emissions intensity is lower in foreign production.

Rankings of levels obtained for the different aggregates of interest in different policy combinations are reported in table 4. Note that fiscal revenues and the country that collects them would also change across policy combinations. For instance, domestic government revenues are expected to be higher in the case of a carbon tax applied to both domestic production and imports. Revenues from border taxation can help fund carbon pricing compensatory policy schemes.

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[25] Balistreri et al. (2019) obtain similar results drive by a positive term of trade effect in a general equilibrium set-up with multiple countries and sectors.

Table 4 Effects of carbon taxation

	Levels ranking
Domestic production	Initial > CT(domestic + border) > CT(domestic + foreign) > CT(domestic)
Domestic demand	Initial > CT(domestic) > CT(domestic + foreign) > CT(domestic + border)
Imports	CT(domestic) > Initial > CT(domestic + foreign) > CT(domestic + border)
Domestic emissions	Initial > CT(domestic + border) > CT(domestic + foreign) > CT(domestic)
Foreign emissions	CT(domestic) > Initial > CT(domestic + foreign) > CT(domestic + border)
Total emissions (Case A)	CT(domestic) > Initial > CT(domestic + foreign) > CT(domestic + border)
Total emissions (Case B)	Initial> CT(domestic + border)> CT(domestic + foreign)> CT(domestic)

Source: Author's own elaboration.

Note: CT reads carbon tax. Case A refers to a situation where domestic production is less carbon-intensive than foreign production; Case B refers to a situation where domestic production is more carbon-intensive than foreign production.

So far, we have only considered genuine responses from the foreign economy. But it can be argued that carbon border taxes could lead to some retaliation if they are perceived as beggar-thy-neighbour policies. Indeed, the border tax may be perceived by trading partners as a "green" protectionist measure implemented to protect local industries from foreign competition rather than to curb overall GHG emissions. Consequently, rather than responding by activating policy channels to respond to mitigate GHG emissions, affected countries may simply in turn raise their barriers to imports from the carbon border tax implementing country. Moreover, a sizeable number of technical, regulatory and legal challenges would have to be overcome (Mehling et al. 2019). An accurate measurement of the carbon content of individual goods may be complex in practice (Droege and Fischer 2020). In principle, all carbon emissions observed throughout the good's entire value chain would have to be captured. However, considering that many production processes with varying carbon intensities could characterize the same good, the imposition of the adequate carbon tax value may become tricky and costly.

An alternative or complementary (symmetric) instrument[26] to a carbon tax on imports would be an export subsidy whose amount would be in line with the carbon tax applied domestically on production. Consequently, exported goods would face the carbon price determined by the country to which they are destined for consumption. In the symmetric scheme only imports and domestic production consumed domestically are taxed, while exports are exempt. This would also imply that the importing country only attempts to curb emissions caused by the production of goods consumed domestically. The resulting impact on both regional and total emissions would be mitigated and could even be positive in the event that the sourcing country responds to the carbon border tax by subsidizing imports.

3.2 CARBON EMISSIONS TRADING

The Kyoto Protocol introduced three "market mechanisms". The first refers to emissions trading systems.[27] The other two are carbon offset mechanisms: the clean development mechanism (CDM), defined in article 12 of the Protocol, and joint implementation (JI), defined in article 6.

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[26] Elliott et al. (2010) define an emission tax that involves a tax rebate for exports as well as a tax on imports a "full" border tax adjustment (BTA).

[27] As discussed in chapter 2, the first cap-and-trade ETS was established in the European Union in 2005.

3.2.1 Emissions trading systems

An emissions trading system (ETS) is a system where emitters can trade emission units to meet their emission targets, which are in most circumstances imposed by some central regulatory political institution.[28] To comply with their emission targets, entities can either implement internal abatement measures or acquire emission units in the carbon market. Their choice depends upon some arbitrage of relative costs: the higher the market price, the more expensive it is to use a permit (either to use it directly or to avoid selling it on the market). Therefore, as the price increases on the market, so do the incentives to reduce emissions. By confronting supply and demand of emission units, an ETS would define a market price for GHG emissions that varies with relative supply and demand conditions.

The two main types of ETS are cap-and-trade and baseline-and-credit. In cap-and-trade systems, a cap or absolute limit on the emissions within the ETS is defined and emissions permits corresponding to that cap are distributed. The figure in Annex 1 1 shows that if the cap is at E*, competitive trade of emissions permits would establish the equilibrium price P* which is equivalent to the optimal carbon tax t*. Permits can be distributed either free of charge or through auctions. A major recognized advantage of auctioning is that associated rents are captured by public authorities and not by the CO2 emitters themselves.[29]

In baseline-and-credit systems baseline emissions levels are defined for individual regulated entities and credits are issued to entities that have reduced their emissions below this level. These credits can be sold to other entities exceeding their baseline emission levels. Cap-and-trade and baseline-and-credit systems should in principle lead to the same long-run equilibrium, at least in terms of total emissions, if baseline information is correct. However, the long-run equilibria of the two approaches would differ if baselines in the baseline-and-credit system are proportional to output.[30] Proportionality to output would imply a variable baseline and that would be equivalent to an output subsidy. Consequently, firms receiving this subsidy will tend to increase their output, that is emissions, and eventually external costs will rise. However, baseline-and-credit and cap-and-trade plans would be equivalent if the cap implicit in the baseline-and-credit plan is fixed and numerically comparable to the fixed cap in a cap-and-trade plan.

3.2.2 Carbon offset mechanisms

These mechanisms are based on carbon offset projects that seek to avoid or absorb a specified amount of carbon emissions while selling credits for the resulting carbon reduction. Projects earn units not by reducing emissions below a set cap, but by reducing emissions below some baseline reflecting the level of emissions that would have been observed in the absence of the project.

Carbon offset projects can be run either by government bodies (compliance carbon offset programmes) or by NGOs (voluntary carbon offset programmes) as reported in table 5. In compliance markets, a government agency establishes the regulatory framework, indicating the types of offset projects that are permitted. The use of compliance carbon offsets to obtain emission credits is in most cases limited as offsets programs can provide cheaper alternatives than emissions reductions within sectors covered by emissions caps. In contrast, offsets sold on voluntary carbon markets typically follow rules defined by voluntary standards bodies (e.g. the Gold Standard or the Verified Carbon Standard). In these unregulated

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[28] Emissions can, in principle, be of any GHG (e.g. methane -CH4-, nitrous oxides -N2O-, fluorinated gases -F-gas-) even though in practice it is still essentially about carbon dioxide (CO2) due to its predominance in terms of warming effect.

[29] See Cramton and Kerr (2002), OECD (2008) for a broad general discussion and Metcalf (2019) for a presentation of cap-and-trade programmes.

[30] See Buckley et al. (2006) for a detailed presentation of the theoretical argument and some evidence from a laboratory experiment.

sectors, purchases of credits are voluntary and are not confronted in most cases with government regulations.

Table 5 Major carbon offset and labelling programmes

"Compliance" carbon offset programmes	Geographic coverage	Label used for offset credits
Clean Development Mechanism (CDM)	Low- and middle-income countries	Certified Emission Reduction (CER)
California Compliance Offset Programme	United States of America	Air Resources Board Offset Credit (ARBOC)
Joint Implementation (JI)	High-income countries	Emission Reduction Unit (ERU)
Regional Greenhouse Gas Initiative (RGGI)	Northeast United States of America	RGGI CO2 Offset Allowance (ROA)
Alberta Emission Offset Programme (AEOP)	Alberta, Canada	Alberta Emissions Offset Credit (AEOC)
"Voluntary" carbon offset and labelling programmes	**Geographic Coverage**	**Label used for offset credits**
American Carbon Registry	United States of America, some international	Emission Reduction Tonne (ERT)
Climate Action Reserve (CAR)	United States of America, Mexico	Climate Reserve Tonne (CRT)
The Gold Standard	International	Verified Emission Reduction (VER)
Plan Vivo	International	Plan Vivo Certificate (PVC)
The Verified Carbon Standard	International	Verified Carbon Unit (VCU)

Source: Based on Broekhoff et al. (2019).

Six major, although non-exclusive, categories of carbon offset projects have been identified and can be found in either compliance or voluntary offset markets.[31] The first category includes projects that develop renewable energy production (i.e. solar, wind, hydro or biomass power). The second category relates to energy efficiency (e.g. distribution of more efficient light bulbs or more efficient cooking stoves). The third category covers industrial gases other than CO2. Projects consist in capturing and/or destroying greenhouse gases emitted during industrial processes, focussing on gases with stronger warming effects compared to CO2, such as nitrous oxide (N2O) or HFC-23. The fourth category includes methane capture projects,[32] whose main objective is to capture the methane released from various activities (e.g. landfills, coal mining, wastewater treatment) and either burn it off or use it as fuel. The fifth category is biosequestration. Projects in this category mainly include tree planting, improvement of forest management, and avoidance of conversion of land to agricultural use to limit deforestation. The last category is carbon capture and storage.

Several criteria have been identified to assess the environmental relevance and efficiency of carbon offset projects.[33] The most common are additionality, permanence, absence of leakage, and verification. Additionality refers to whether the carbon emissions reduction or mitigation would have been observed in the absence of the offset project. Permanence refers to whether the carbon emissions reduction or mitigation continues for the stated time period. Absence of leakage refers to whether the carbon emissions reduced or mitigated in the constrained country do not occur somewhere else and thus merely relocate

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[31] Broekhoff et al. (2019) offer a comprehensive review of offset project types.

[32] Scientific evidence suggests that one tonne of methane is equivalent to 28 to 36 tonnes of CO2 when considering its impact over 100 years (IEA, 2021).

[33] See for instance Broekhoff et al. (2019) for a practical description.

environmental and potentially social damage. Verification implies that a credible authority establishes the previous three criteria independently of the parties involved in the project.

The CDM and the JI are both compliance carbon offset programmes. Both systems issue carbon credits (certified emission reductions (CERs) in the CDM system and emission reduction units (ERUs) in the JI system) according to a predefined accounting protocol.[34] Both have their own distinct registry. A major difference between the CDM and JI lies in the fact that JI projects can only be hosted by developed countries and CDM projects by developing countries. Credits obtained under these schemes can be used to meet compliance under an international agreement, certain domestic policies, or corporate objectives in relation to GHGs mitigation. For instance, companies under the European Union Emissions Trading System (EU ETS) have been able to use CERs and ERUs to cover a part of their obligations during the first three phases of the system. Countries with an emissions reduction obligation under the Kyoto Protocol can also use the units to cover a part of that obligation.

Rules, modalities and procedures were adopted for the new UNFCCC mechanism at COP 26. The mechanism credits emission reducing activities. This enables a company in one country to reduce emissions in that country and have those reductions credited so that it can sell them to another company in another country. That second company may use them to comply with its own emissions reduction obligations or to help it meet net zero. Implementation can, however, prove difficult in practice because the information needed to determine appropriate baseline emissions may not be always available.

Accurate measurement of the emissions once the project is implemented is also crucial as the project earns the difference between baseline emissions and post-project emissions. Rosendahl and Strand (2009) identify two theoretical conditions under which CDM or equivalently JI projects do not lead to full offset of emissions and even possibly lead to an overall increase in global emissions. One condition relates to baseline manipulation (“overestimation”) and the other to leakage. Baseline manipulation could occur if firms conducting CDM/JI projects are incentivized to increase their baseline emissions to optimize the value of CDM/JI credits. Leakage occurs when reductions in emissions due to a CDM/JI project affect market equilibrium in local and/or global energy and product markets, consequently increasing emissions in either non-covered sectors or in third parties. Overestimation and leakage can be associated with any type of carbon offset programme, not only compliance programmes. The incentive for participants in voluntary programmes to deviate from objective estimates may not be as strong in the case of compliance programmes but may still exist in anticipation of future changes in legislation. Voluntary programmes may be recognized as emissions credit generators by legal authorities and would thus become highly monetizable. Limiting fraudulent behaviour and inefficiency is crucial.[35] While the baseline problem can easily be fixed by imposing an exogenous baseline independent of the project, it is more complicated to predict and prevent unfavourable overall market equilibrium effects.

3.2.3 A comparison of emissions trading and offsetting programmes

Trading systems and offset programmes in principle serve the same purpose – to reduce overall emissions of GHGs – and both can be an integral element of governments’ climate action plans. However, whereas

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[34] Note that the possibility for voluntary cancellation has recently been included in the CDM registry. Voluntary cancellation allows project participants who hold certified emission reductions (CERs) in the CDM registry to cancel them on their own behalf or on behalf of third parties. This gives them access to a broader source of demand for CERs in the voluntary market. Details are available at https://cdm.unfccc.int/Registry/guidance/index.html#voluntary_cancellation.

[35] As part of the UN’s climate action efforts, a UN Secretary-General’s Net-Zero Expert Group was established in April 2022. Its main mission is to develop stronger and clearer standards for net-zero emissions pledges by non-State entities – such as businesses, investors, cities and regions – and speed up their implementation. More details at https://news.un.org/en/story/2022/04/1117062.

in a trading system emissions reductions are directly linked to the sector covered by central allowances, this does not have to be the case in offset programmes.

Offset programmes can be implemented in sectors other than the emitting sector. In the CDM and JI mechanisms, there is also the obligation for projects to be conducted in a different country. Experiences with projects related to carbon flows in land use, land-use change and forestry (LULUCF)[36] have shown that including nature-based mitigation offsets in national mitigation targets can create loopholes leading to leakage and/or measurement, reporting and verification (MRV) challenges. Offsetting may reduce the ambition of mitigation in other sectors and can lead to lock-in of carbon-intensive infrastructure. This should not be observed in an ETS as emissions reductions are targeted to a given sector and firms' reduction objectives are linked to their own production activities.

However, both carbon pricing schemes share the common feature of high price volatility. This is essentially a reflection of complex administrative requirements such as the definition of levels of emission allowances in the case of ETSs and utilization of offset credits in government mitigation plans. Such complexity explains to a large extent the collapse of the CDM in 2012[37] and the significant drop in prices in the EU ETS observed over several periods since its inception in 2005.[38] Note that CDM were intended to be used as international credits for EU ETS compliance only until the end of phase III of the EU ETS in 2020.

3.3 A COMPARISON OF CARBON TAXES AND EMISSIONS TRADING

In practice, carbon taxes and cap-and-trade systems are the two main approaches to carbon pricing. The relative merits and flaws of these two approaches deserve some attention[39] and may also relate to other carbon pricing instruments. Both carbon pricing instruments can be in place simultaneously. If applied to the same set of sectors they may be perceived as redundant and may not send a clear signal about the pricing strategy adopted by the imposing authority. It may be the case that each instrument applies to different sets of sectors. Even in this case, whereas the carbon price would be pre-determined with the use of a carbon tax, it may differ significantly from the equilibrium price observed in the trading system. Price divergence could be an issue, both on equity and efficiency grounds. Complementarity between the two instruments may be difficult to operationalize. The most suitable approach to emissions reduction is likely to depend on the specific circumstances and context of a given jurisdiction.

From a more general point of view, there is no unambiguous finding favouring either a quantity or a price instrument in the presence of uncertainty about abatement costs (represented by the curve BB in figure 1) and/or damage/benefits (represented by the curve DD in figure 1). The ranking of price over quantity instruments when dealing with externalities such as GHG emissions does not hold systematically as was the case in the original setting analysed by Weitzman (1974). Defining this ranking has become an empirical question requiring advanced simulation analysis. Karp and Traeger (2018), using an augmented version of the Nordhaus's (2015) dynamic integrated model of climate and economy (DICE), find that, under many circumstances, the quantity instrument is superior to the price instrument. Their analysis suggests that quantity instruments can be more efficient in addressing climate change than price instruments. However, several additional features would have to be considered before reaching any definitive conclusion. In

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[36] See for instance Fyson and Jeffrey (2019).

[37] See Kainou (2022) for a detailed analysis.

[38] See for instance Sanin et al. (2015) and Jiménez-Rodríguez (2019) for an extensive discussion and empirical evidence.

[39] See Starvins (2022) for an extensive review of analytical and practical arguments developed since the seminal work of Wietzman (1974).

particular, the efficiency of the quantity instrument is known to be highly dependent on the competitiveness of the underlying permit market. It has been shown that firms with a high share of permits (e.g. electricity generating firms on the European market) used their market power to manipulate the permit price and increase their windfall profits.[40]

A carbon tax puts a price, whether explicit or implicit, on CO2 emissions. The reaction of producers and consumers to that price determines the effective quantity of emissions. In other words, the price is imposed by a central entity, while the level of emissions is a market outcome. In the presence for instance of asymmetric information about firms' abatement costs, or uncertainty about consumers preferences, this implies that the environmental outcome can be only imprecisely anticipated. In the context of emissions trading based on a cap-and-trade system, the carbon price becomes the market outcome, while the level of emissions is determined by a central entity. Even if the market where the buying and selling of rights to emit (subject to the cap) operate is tightly regulated, it eventually determines the market clearing price. Whereas carbon taxes can be accompanied by uncertainty about emissions levels, cap-and-trade systems can lead to price volatility and firms would thus have to deal with profitability uncertainty when deciding for long-lived, capital-intensive projects.

Cap-and-trade systems must be based on specific regulations and are often subject to complex administrative processes. They require a fully dedicated administrative structure to create and monitor emissions allowances, facilitate auctions or otherwise freely allocate them, and develop rules to avoid fraudulent and abusive behaviour.[41] As discussed previously, administrative complexity could also be a prominent feature of offset programmes such as the CDM. Administrative complexity is considerably lower in the case of domestic carbon taxes especially if the countries imposing these have robust tax collection systems. However, the implementation of carbon border taxes is also regarded as complex and open to dispute from those trade partners facing it.

Taxes and cap-and-trade systems interact differently with possible additional policies enacted to reduce emissions. Gros (2009) shows that if the importing country has a cap on emissions instead of a carbon tax, implying that the price of carbon is endogenously determined, a carbon border tax is always beneficial from a global welfare point of view. Moreover, with a cap-and-trade system the optimal carbon border tax rate does not depend on the domestic price of carbon. Therefore, a carbon border tax may not be consistent with international trade rules.

In more realistic conditions, the results may need to be somewhat nuanced. In particular, the fact that not all sectors are covered by carbon pricing may lead to mixed conclusions. For instance, in sectors covered by a cap-and-trade programme, any additional scheme or instrument with such scope (e.g. offset programmes generating credits that can be integrated, even partially, into the trading system) will not affect overall emissions. Indeed, assuming the cap is binding, emissions reductions obtained via these supplementary programmes are offset by increases in emissions somewhere else. If the cap is not binding, then supplementary programmes would contribute to an oversupply of emissions credits. Depending on the set of regulations in place, oversupply could undermine allowance prices in the cap-and-trade system or increase current and future emissions.[42]

Designing a carbon border tax scheme may be more straightforward in the presence of domestic carbon taxes than in the presence of a trading system based on a cap-and trade approach. Assuming

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[40] See Hinterman (2017) for a theoretical discussion and empirical illustration based on the EU ETS.

[41] Administrative complexity clearly emerged during the first phase of the EU ETS. During that phase GHG emissions increased by 2.1 per cent (i.e. about 130 million tonnes) more (+2.1 per cent) with respect to pre-scheme levels. As a result, the price of carbon permits collapsed and never recovered during that phase. From a peak of around €30, the price fell below €10 in April 2006, and below €1 in 2007.

[42] See Metcaf (2021) for a detailed discussion.

emissions observed during the production process of imported goods (and services) are precisely known, a natural candidate for the border tax rate would be the domestically applied rate. In adopting such a rate, implementing authorities would still respect WTO rules, which allow countries to apply duties on imports or apply rebates on export as long as they do not exceed domestic taxes on comparable domestic products or their inputs.[43] The scheme would, however, have to be consistent with the national treatment principle that imposes equal treatment of domestic and foreign trade entities.[44]

Setting the tax rate to be imposed on imports may not be so straightfroward in the presence of a trading system. Because the price of allowances traded varies according to the supply and demand conditions prevailing on that market, a perfect equivalence between the domestic price of carbon and that imposed on imports could not be guaranteed. This non-alignment of prices would lead to a situation of either unfair competition from or discriminatory treatment against foreign goods. The latter situation may thus give rise to a formal dispute in the WTO context.

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[43] In accordance with GATT Article III:2 in combination with GATT Article II:2.

[44] See Prag (2020) and Mehling et al. (2019) for recent detailed discussions.

Chapter 4

Market-based approaches to carbon pricing: Quantitative and empirical assessment

Chapter 3 presented theoretical insights into market-based approaches to carbon pricing. The effects were essentially of partial equilibrium nature obtained with a single representative sector approach and focusing on trade/production and GHG emissions. Although partial equilibrium effects are useful when qualitatively defining the consequences of policy intervention, obtaining quantitative results requires more sophisticated analytical tools based on either ex-ante or ex-post analysis (box 3).

4.1 ECONOMIC AND ENVIRONMENTAL EFFECTS OF CARBON PRICING

Different types of carbon prices may affect the various economic agents and sectors differently. As discussed previously, different types of carbon prices may also have different environmental effects. Existing studies principally offer impact estimates of either tax-related carbon pricing or ETS.

Given that the use of carbon pricing is a relatively recent policy, which means that the relevant empirical evidence available is limited, the use of ex-ante approaches based on integrated assessment models (IAMs) is still predominant. However, IAMs focus mainly on tax-related instruments. This is because the economic structure and relationships of IAMs are driven essentially by price effects. Taxes of any sort (e.g. emissions taxes, tariffs) can easily be translated into price effects. This may not be the case of ETS equilibrium prices. Predicting the dynamics of such markets is not straightforward, and their integration into general equilibrium types of models may be complex.[45]

4.1.1 Domestic carbon pricing schemes

Notwithstanding all the possible sources of differences in results, some qualitative patterns can be retrieved. On the whole there is consensus in the literature that carbon pricing results in a significant negative effect on GHG emissions. As expected, the effect seems to be stronger in sectors with relatively inelastic demand (e.g. transport). However, emissions reductions are associated with output and employment losses where complementary and compensatory policies are not implemented. Direct transfers to households appear to be the most effective policy to contain the negative impact on economic aggregates.

4.1.1.1 Ex-ante analysis

As seen in the previous chapter, in a partial equilibrium context the implementation of a carbon pricing instrument is expected to negatively affect both emissions and production. This is also observed in most general equilibrium simulations. Annex 2 summarizes results obtained in recent studies assessing the impact of carbon pricing schemes in developing countries.

The trade-off between emissions reduction and economic activity is almost systematic. In addition, when reported, employment is also expected to decrease as a consequence of emissions reduction. However, the impact on production and possibly employment can be mitigated by some complementary policies financed by the revenue collected through carbon pricing. As argued in Fullerton and Metcalf (2020), implementing carbon taxes without accounting for existing distortions in the commodity and factor markets may “miss the target” of reducing GHG emissions in a cost-effective manner. The role of recycling revenue from carbon pricing is directly associated with the “double dividend” argument. This argument points to the possibility of using environmental tax revenues to reduce pre-existing taxes. This could generate an

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[45] A simplified emissions trading system (e.g. Bekkers and Cariola, 2022) can consist of applying a predetermined price (e.g. the domestic carbon tax if implemented) to the quantity of GHGs emitted domestically. Differences between emissions allowances and their observed level would translate into some emissions trading recorded in the emitting entity trade balance.

additional or “double” benefit: one benefit from environmental improvement through lower emissions and a second benefit from reducing distortions from other revenue-motivated taxes.

The reconciliation between environmental policy and economic activity thanks to complementary policies is illustrated by several studies presented in annex 2. Landa Rivera et al. (2016) investigate the impact of policy reforms aimed at reducing GHG emissions in line with Mexican government objectives. A first policy experiment looks at the impact of removing subsidies together with the introduction of a carbon tax but with no revenues recycling. Another policy experiment uses lump-sum transfers to redistribute revenues from subsidies and carbon taxes to both producers and consumers. The results suggest that the negative impact on GDP observed in the first experiment can be reduced by more than 60 per cent when redistribution occurs. Several studies such as Grottera et al. (2017) for Brazil, Liu and Lu (2015) for China or Ojha et al. (2020) for India, further suggest that recycling carbon tax revenues in favour of productive activities (e.g. endogenous corporate or production tax) can limit the negative effects on GDP more significantly than any other redistributive scheme. Some other studies, such as Telaye et al. (2019) for Ethiopia or Nurdianto and Resosudarmo (2016) for several ASEAN countries, suggest that lump-sum transfers may be preferable to proportional tax reductions.

To assess policy reform options more precisely, their respective cost-effectiveness, or a proxy of it, can be calculated. For instance, in Grottera et al. (2017), for a carbon tax of $4.7/tCO2e a 1 per cent reduction in emissions would be associated with a 0.52 per cent decrease in GDP under a no-recycling policy scheme. The GDP decrease would fall to 0.38 per cent in the presence of endogenous consumption tax. In the case of an endogenous production tax, a 1 per cent reduction in emissions would even be associated with an increase in GDP of 0.1 per cent. In Wattanakuljarus (2019), results indicate that recycling tax revenues via social transfers leads to a lower carbon price and a smaller fall in GDP for the same amount of reduced emissions. In case of no-recycling policy, a $1/tCO2e tax is associated with a GDP fall of 0.69 per cent. With recycling, the latter figure drops to 0.62.

Zhou et al. (2022) are among the few researchers who have established proper cost-effectiveness comparisons between a cap-and-trade system and a carbon tax. Based on computable general equilibrium (CGE) model simulations, the authors assess the cost-effectiveness of various policies based on shadow carbon prices. Their results indicate that a carbon tax is the most cost-effective of the two carbon pricing policies. A cap-and-trade system would be less impactful at the sector level than a carbon tax especially when the cap restriction is loose. Results found by Nong et al. (2020) further suggest that the broader the sectoral coverage the smaller the negative impact on GDP and the greater the impact on emissions reduction. These results reflect a lower carbon price at equilibrium with full sectoral coverage (i.e. $36/tCO2e) as compared to partial sectoral coverage (i.e. $109 /tCO2e).

4.1.1.2 Ex-post analysis

Several countries have adopted carbon taxation. Both applied tax rates and sectoral coverage have varied greatly from one country to another. The level of disaggregation in the information used may also vary across studies. Direct comparisons may therefore not always be possible, although some patterns still emerge.

Aggregate and sectoral evidence

Lin and Li (2011) offer an important assessment of early carbon taxation schemes in several European countries. Applying standard differences-in-differences techniques, they estimate reductions in emission growth rates due to carbon taxation in Sweden, Denmark, Finland, Norway and the Netherlands. The mitigation effect of established carbon taxes differs across countries. A significant effect is obtained for Finland only. The effects of carbon tax in Denmark, Sweden and Netherlands are negative but not significant. In Norway, the estimated effect is positive but not statistically different from zero. Differences in estimated effects are due to differences in the design of policy schemes and in revenues recycling. Finland imposed a relatively low flat rate tax on a relatively substantial number of sectors. This is the main reason for the better performance of the Finnish tax scheme in terms of emissions reduction. The fact that Sweden, Norway, Netherlands and Denmark provided tax exemption to manufacturing industry and related energy-intensive industries to preserve international competitiveness explains the non-statistically significant mitigation effects in these countries. Norway's experience points to the difficulty an exporter of energy products may face in establishing efficient mitigation policies. GHG emissions in the domestic energy exploitation industries such as oil drilling and natural gas exploitation are predominantly driven by foreign demand. This trend explains to a large extent the poor mitigation effects of the carbon tax in Norway. The Danish and Dutch experiences show how the recycling of tax revenue to enterprises for environmental purposes can promote the development of renewable energy. The Swedish approach also suggests that carbon taxes, if high enough, robustly incentivize firms' emissions abatement efforts even in the absence of revenue recycling.

There is limited evidence of strong effects on GHG emissions. Green (2021) provides a meta-review of ex-post quantitative evaluations of carbon pricing policies around the world since 1990. Most studies, in line with the findings of Lin and Li (2011), indicate that the aggregate reductions from carbon pricing on GHG emissions are limited – generally between 0 per cent and 2 per cent per year.

However, mitigation effects appear to be more significant when estimated using more disaggregated information. For instance, Petrick and Wagner (2014) find that German manufacturing firms reduced their emissions between 25 per cent and 28 per cent relative to unregulated firms between 2008 and 2010. Wagner et al. (2016) observe that French manufacturing firms reduced emissions between 13.5 per cent and 9.8 per cent during the same period, mainly due to fuel switching. Pretis (2019) finds the carbon tax introduced in British Columbia in 2008, the first in North America, resulted in a 5 per cent reduction in transport[46] emissions. Differences-in-differences estimation also suggests a reduction in agricultural emissions, although this is uncertain and not robust across implemented econometric methods. The point estimate of the carbon tax impact on industrial emissions is also negative but imprecisely estimated. However, there is no statistically significant effect of the carbon tax reform on aggregated CO2 emissions. Policy interventions beyond carbon pricing or accompanying it may, as previously discussed, explain such diversity in empirical estimates. As discussed, and documented in Pretis (2019), heterogeneity in emission elasticities across sectors may be an additional factor to consider when assessing carbon tax effects.

The latter finding and argument are echoed in Andersson (2019), who estimated the carbon tax elasticity of demand for petrol in Sweden. Andersson's (2019) empirical strategy points to flaws in earlier studies possibly responsible for the lack of robust evidence in favour of carbon taxation. Based on more advanced empirical techniques able to identify causation more precisely, estimates of elasticities imply that carbon taxation reduced emissions in the transport sector by 6 per cent on average per year between 1990 and 2005. The results also indicate that the tax elasticity of demand is three times larger than the corresponding price elasticity. In other words, consumers appear to be more reactive to carbon taxes than to changes in market prices. Results in both Pretis (2019) and Andersson (2019) indicate that carbon taxes could be more effective in reducing greenhouse gas emissions and air pollution than projections obtained in the previously reviewed simulation studies.

Firm/plant level evidence

As seen in the previous section, the more granular the analysis, the more precise the empirical estimation. For instance, Ahmadi et al. (2022) study the emission impacts of the British Columbia carbon tax in

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[46] The single largest source of emissions in British Columbia since the introduction of the fiscal reform.

the manufacturing sector at plant level. While the point estimate of the carbon tax impact on industrial emissions was imprecisely identified in Pretis (2019), Ahmadi et al. (2022) findings point to marginal but statistically significant reductions in emissions.

Another advantage of using firm/plant information is the possibility, although not systematic, of examining the combined emissions and economic effects of carbon pricing. Martin et al. (2014) find that the carbon tax[47] on electricity consumption implemented in the United Kingdom in 2001 reduced energy intensity by 18 per cent and electricity use by 23 per cent. However, no negative effects are observed on plant employment, revenue, productivity or plant closure. Flues et al. (2015), investigating the German experience, find no substantial effects of an electricity tax on firm turnover, exports, value added, investment or employment.

4.1.2 Carbon border measures

Carbon border measures such as carbon border taxes, or more generally speaking carbon border adjustment (CBA) schemes, have not yet been fully implemented. Hence, evidence of their effects is obtained exclusively using ex-ante analysis tools. Carbon border measures have been simulated in various contexts. As discussed in the previous chapter, such measures are expected to affect production, both domestic and foreign, through their direct impact on trade flows. The introduction of a carbon border tax to contain possible carbon leakage appears to work efficiently while also reducing downward pressures on GDP. Importantly, carbon border adjustment schemes provide incentives for exporting countries to implement their own carbon pricing policies

Alton et al. (2014) simulated the impact of a domestic carbon tax introduced together with a carbon border tax under different redistributive schemes. The inclusion of a carbon border tax appears to further reduce emissions while containing downward pressures on GDP. The imposition of carbon border taxes by trade partners alone is also expected to reduce domestic production as discussed previously.

Bekkers and Cariola (2022) offer an extensive analysis of various carbon pricing schemes including CBAs, based on simulations using an augmented version of the WTO Global Trade Model. In the different scenarios, they consider different degrees of policy integration at the international level. The four sets of climate mitigation policies investigated are a carbon club with uniform tariffs, carbon pricing with symmetric CBA, global carbon pricing with a global incentive scheme (i.e. a global carbon fund in the spirit of the “Global Carbon Incentive” elaborated in Rajan (2021)), and emissions trading with a progressive distribution of emission targets imposing more stringent emissions reductions on developed than developing countries.

Their results indicate that a carbon club à la Nordhaus (2015),[48] comprised mostly of developed countries, can be effective in motivating non-participants, mostly developing countries, to join the club. It may even become essential for non-participating countries to join, as their exports and potentially GDP are expected to decrease because of the uniform tariffs imposed by countries in the carbon club. Carbon border taxes do not appear to induce strong enough incentives for non-ambitious countries to introduce carbon pricing domestically. Results further indicate that a global carbon fund would involve substantial transfers from higher-income to lower-income regions. However, it would not create strong enough incentives for less-ambitious regions to introduce domestic carbon pricing.

The first CBA mechanism, the EU CBAM, will be implemented in the European Union in 2023 with a transition period of at least 3 years (box 4). Bellora and Fontagnié (2022) assess the effects of the EU CBAM using a dynamic CGE model (Mirage-e) with a baseline evolution for the world economy up to

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[47] The so-called Climate Change Levy (CCL) package. The CCL is a per unit tax payable at the time of supply to industrial and commercial users of energy. It was first announced in March 1999 and came into effect in April 2001.

[48] Members of the climate club would introduce domestic carbon taxes and impose a uniform tariff on non-participants to incentivize them to join the club.

2040. The model links trade and GHG emissions taking stock of global value chains (GVCs), imperfect competition, substitution among energies, and substitution among capital and energy. In all scenarios the CBAM applies to all ETS sectors to respect the WTO agreement as discussed previously. CBAM is phased in as free allowances are phased out over a ten-year period. Results suggest that the phasing-out of free allowances and their replacement by a CBAM does respect emissions-reduction targets, but that this comes at some economic cost. These costs are a major consequence of an increase in the ETS price of carbon, resulting from the policy reform. The CBAM only partially compensates this carbon price increase. Differences in economic impacts reflect differences in the reference emissions used for compensation. The use of the emissions of the exporting country instead of the European Union average emissions appears to be more effective in reducing European Union imports of carbon-intensive products. GDP decreases in all scenarios but to a lesser extent when the border mechanism applies only to imports keeping exports out of the scheme. Results further suggest that thanks to the EU CBAM the burden of the climate policy is shared more equally among the sectors covered by the ETS. However, the price of ETS allowances increases, ETS products used as intermediate consumptions by downstream industries are more expensive, and in the absence of rebates ETS producers do not benefit from free allowances allocations on their export markets.

4.1.3 Emissions trading

Emissions trading at the global level with progressive emissions-reduction targets provide incentives for most regions to join a cap-and-trade system. Developing countries would be able to cash in revenues by selling their unused emissions allowances to developed countries whose emissions-reduction efforts are more demanding. Emissions trading would allow some revenue transfer from developed to developing countries as in the case of the global fund scenario. However, while a global fund would certainly be exposed to depletory effects of broader country participation, this rivalry effect is much weaker in a global trading system. Simulations further indicate that the costs for the developed countries would be higher under a global fund because net payments to the carbon fund would be much larger than the cost of buying emission rights.

Aggregate and sectoral evidence

Evidence on ETSs and cap-and-trade policies also offer some important insights. Fowlie et al. (2012) provide some estimates of the effect of an ETS on emissions in California. Their results indicate that emissions at plants that were included in the emissions trading policy fell on average by 20 per cent. Studies of the EU ETS point to relatively modest average annual reductions ranging from 0 per cent to 1.5 per cent as reported in Green (2021). Klemetsen et al. (2016) even found that in Norway the ETS did not have any effect on emissions. In France, Wagner et al. (2016) found that the EU ETS reduced emissions by 15 per cent but only during phase II (2008-2012) of the system's implementation. Petrich and Wagner (2014) looked at a similar issue using German data. It appears that the EU ETS could have contributed to a reduction in emissions of 20 per cent, although again only during the second phase of the system's implementation. Differences in results obtained for different phases of the EU ETS are certainly linked to the differences in regulatory features prevailing in each phase. The significant impact on emissions found during phase II can be partly attributed to the imposition of a tighter emission cap and the introduction of a partial auction system.

As discussed in Greene (2021), based on existing empirical evidence, carbon taxes appear to perform better than emissions trading schemes in terms of mitigation effects. However, differences in results may also be due to differences in empirical strategies. These are not always completely reliable in terms of identification strategy. Moreover, comparative results should be interpreted cautiously as the timespan of most carbon pricing instruments has not been long enough to generate solid medium- to long-term statistical regularities.

Firm/plant level evidence

Dong et al. (2019) investigate the impact of pilot ETSs implemented in several Chinese provinces on reducing carbon emissions during the initial stage between 2013 and 2015. Working at the subsector level in each Chinese province, the authors are able to account for both direct and indirect carbon emissions and avoid possible bias in estimation due to miscalculation of total carbon emissions in the various subsectors. Results yield robust evidence that China's pilot ETSs have significantly promoted carbon emission reductions in the industrial subsectors covered, and that this impact has presented an overall enhanced trend according to year-by-year analysis.

As in the case of carbon taxes, ETSs also generate effects beyond emissions. In Norway for example, Klemetsen et al. (2016) find that the EU ETS increased firms' value added and productivity during phase II. Using data for France, Wagner et al. (2016) show that the EU ETS caused employment in covered sectors to decrease by 7 per cent during that same trading phase. Petrich and Wagner (2014) show that in Germany the EU ETS did not reduce firm's employment, turnover or exports.

Dechezleprêtre at al. (2018) assess the impact of the EU ETS on both carbon emissions and economic performance in several European countries (i.e. France, the Netherlands, Norway and the United Kingdom). Their empirical strategy is based on a combination of macro and micro data. As compared to previous firm/plant level studies, causal relationships can be more robustly identified. The authors apply a matched differences-in-differences study design to installation-level data from the national Pollutant Release and Transfer Registers. The EU ETS not only led to a statistically significant reduction – in the range of 10 to 14 per cent – in carbon emissions, at least during the second trading phase, but also led to a statistically significant increase in revenue and in fixed assets of regulated firms. ETS firms' revenues were 16 per cent higher on average than non-ETS firms' revenues, and their fixed assets were about 8 per cent higher. The impact on fixed assets may be due to the adoption of emissions-reduction technologies by covered companies. These results are robust to various sensitivity checks. The high granularity of the authors' data set further allows them to assess the impact of free allocation of emissions allowances. Their results indicate that emissions would have been reduced by around 25 per cent if the share of allowances freely distributed had been halved.

Zhang and Duan (2020) find that pilot ETSs in China had a statistically significant negative impact on gross industrial output value and employment in covered industrial subsectors. Moreover, their estimates show a decreasing trend between 2013 and 2015, indicating the negative impact of pilot ETSs increased year after year. The impact of pilot ETSs on carbon intensity is also investigated. Results corroborate those in Zhang et al. (2019) and suggest that the pilot ETSs significantly promoted carbon emission reductions, but without affecting the carbon intensity of covered subsectors.

Box 3 Main approaches to assessing carbon pricing impacts

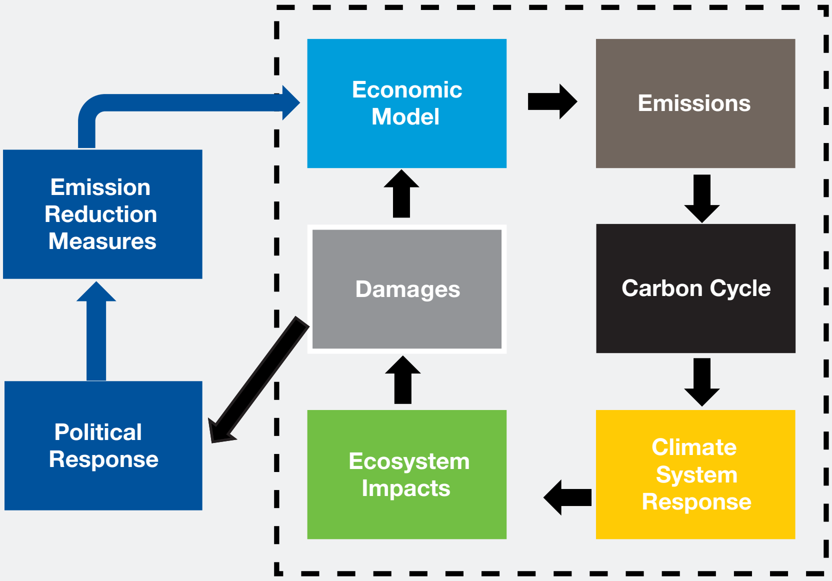
Three main categories of assessment approaches applied to carbon pricing instruments can be identified. The first category allows for the projection of the impact of a carbon pricing scheme, while the other two categories allow for the evaluation of the impact of carbon pricing schemes implemented in the past.

Ex ante analysis

The first category includes all computable economic models used for the ex-ante assessment of carbon pricing policies. These models are usually referred to as integrated assessment models (IAMs). They include a large set of general equilibrium nexuses as schematized in the figure below and allow for the calculation of the net present value of the current and expected future costs and benefits of a policy reform and action. The confrontation of costs and benefits and present values determines cost-effectiveness.

In the context of climate-related policy, several computational steps are required to obtain such information. To start with, climate changes in relation to GHG emissions must be determined under both the policy scenario to be assessed and a "business as usual" situation. Projections for future emissions of CO2 and other GHGs, as well as estimates of atmospheric GHG concentrations, are needed under all considered scenarios. Emissions and atmospheric concentrations of GHGs must then be translated into global or regional temperature changes, along with any other climate change dimension of interest. The second set of computational steps involves the economic sphere. Changes in economic aggregates likely to result from higher temperatures and other climate changes must be defined. Such changes will vary depending on the set of parameters chosen to represent interactions between climatic conditions and economic activity. As emissions reductions imply in most cases some abatement costs (e.g. the amount of the carbon tax), such costs or some representative functional form should also be integrated into the economic model.

Modelling components in generic integrated assessment models



Source: Based on Metcalf and Stock (2017).

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All steps may involve some uncertainty about the value to be taken by various, often important, parameters. For instance, a crucial role is played by the social rate of time preference chosen to compute present values. As discussed extensively in Pindyck (2017) disagreement about the nature and extent of the uncertainties still exists and may imply contrasting conclusions about the path of climate policy to be followed.

A new class of dynamic economic assessment models has recently emerged (e.g. Cruz and Rossi-Hansberg, 2021). These models offer high spatial resolution to assess the consequences of climate change. They feature several forms of adaptation to local temperature changes, including costly trade and migration, local technological innovations, and local natality rates. However, these are also subject to concerns about the uncertainty of structural parameters' values.

Ex post analysis

The second category of approaches includes all empirical studies proposing an ex-post assessment of implemented carbon pricing instruments. Empirical techniques encompass both cross-sectional and panel estimations with now standard strengths and weaknesses applying. Because of the short period of assessment faced in most cases but also the succession of shocks, whether sectoral or global during that period, causal relations between carbon pricing and environmental and economic outcomes have been difficult to identify. Weak identification could help explain the large differences observed in empirical findings[49] but also makes the understanding of the effectiveness and impact of carbon pricing policies challenging.

A third category has recently emerged and includes all research studies based on quasi-experimental designs. This approach is also based on an ex-post evaluation of policy reforms. However, quasi-experimental empirical exercises are in principle able to identify causal relationships more precisely. They exploit variation in policy not only over time but also within a specific spatial area, controlling for the influence of circumstantial elements and more structural features. These studies can thus estimate whether a causal relation exists between a given carbon pricing instrument, GHGs emissions and economic outcomes such as output, employment and productivity. Such results constitute new insights into the implementation of carbon pricing policies and their effectiveness both in terms of emissions reductions and economic efficiency.

4.2 DISTRIBUTIONAL EFFECTS

Distributional effects occur within the country implementing a carbon pricing policy. Distributional effects can emerge across firms and within or across sectors. Carbon taxes are found to be regressive in some developed economies, but this is not necessarily the case in all developing countries. The degree of regressivity appears to depend on country-specific characteristics. Carbon pricing instruments imposed by some countries could also affect economic outcomes in other countries. This is particularly the case of carbon border adjustment instruments. Positive terms of trade effects are obtained in imposing countries, as suggested by theory. Trade effects are also observed and may correspond qualitatively to those that would be obtained in the context of the formation of a regional trade agreement. Both trade creation and trade diversion can be observed. Participation in an ETS to benefit relatively larger firms to a greater extent than it benefits smaller firms. Carbon taxes and cap-and-trade systems can be designed to generate similar distributional effects among participating firms.

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[49] Andersson (2019) and Fried et al. (2021) provide a detailed discussion.

4.2.1 Carbon domestic tax

Dorband et al. (2019) adopted a computational approach allowing for a consistent comparison of effects across a large set of countries. Using a microsimulation model coupled with the econometric estimation of energy Engel curves,[50] they simulated the impact of a \$30 per tCO2e carbon tax on 87 low- and middle-income countries. Their results indicate that the simulated carbon tax would be progressive for lower income countries and regressive for higher income countries. The strongest regressive effect is found for Bosnia and Herzegovina. The lowest income group of households would, relative to their income, pay more than three times as much as the country average. In Belarus, Serbia, Montenegro and South Africa the corresponding figure is 1.5 times. Progressive outcomes are found for most Sub-Saharan African countries, and lower income countries in South-East Asia and Latin America. On average, the carbon tax is expected to display progressive effects on the income distribution in countries with per capita incomes of below roughly \$15,000, while having regressive effects in higher per capita income countries. The \$15,000 threshold can be explained by the finding that energy expenditure shares increase up to a household per capita income around \$8,000–10,000 (adjusted by a purchasing power parity deflator) and decrease thereafter. This relational feature is largely due to the different pattern of energy expenditure between urban and rural households. Higher income countries are more urbanized than lower-income countries. As urban households typically use more transportation than rural ones and only have access to taxable energy sources, the impact on poorer households is stronger in relatively higher-income countries.

Another important and politically crucial distributional dimension involves households. Household distributional impacts of carbon taxes and cap-and-trade systems can be similar. Policy equivalence will depend not only on the extent of free emissions, as in the case of firms, but more so in the use of revenue.[51] As shown in the previous section, the latter feature plays a significant role in defining, for instance, employment effects. The impact of carbon pricing on households is defined by two components. The first component, the so-called "use-side impacts", refers to the policy impact on the relative prices of goods and services purchased by households and consequently on household expenditure. The other component, the so-called "source-side impacts"; reflects the policy impact on nominal wages, capital and transfers and, consequently on household income. Carbon pricing is generally regressive[52] on the use side as lower-income households tend to dedicate a larger share of their income to expenditure on goods of primary necessity, which are more carbon-intensive than any other goods. However, on the source side, effects on wages and capital returns are generally progressive. This reflects the fact that carbon-intensive industries (which, of course, face the greatest burden from a carbon tax) tend to be relatively capital-intensive. As a result, the burden of a carbon tax falls more on capital than on labour, and hence tends to reduce returns on capital more than returns on labour. Since capital income represents a larger share of total income in wealthier households than in poorer households, the impacts from reduced returns on capital are progressive. Progressivity would also characterize government income transfers. This would clearly be the case with lump-sum transfers which, by definition, affect higher incomes to a proportionally lesser extent. Source-side impacts generally dominate use-side impacts in most cases where some form of revenue recycling policy is implemented. Andersson and Atkinsons (2020) show that the Swedish carbon tax is increasingly regressive over time, which is highly correlated with a rise in income inequality in the country. However, they also show that the tax incidence moves from regressive to progressive when switching from annual income to the more evenly distributed measure of lifetime income.

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[50] The energy Engel curve depicts the systematic relationship between income and energy expenditures. This relationship plays a vital role in framing distributional outcomes of carbon pricing as discussed in Levinson and O'Brien (2015).

[51] See for instance in Metcalf (2016) and Stavins (2022) for an extensive discussion.

[52] A regressive policy implies a larger financial burden as a share of consumption – or income – on lower-income households than on higher-income households; a progressive policy implies the opposite.

Thus, in the presence of a comparable revenue recycling policy, the overall impact of carbon pricing is likely to be progressive, whether we consider carbon taxes or cap-and-trade with no free allowances granted. Using the tax or auction revenue for lump-sum rebates would make carbon pricing schemes even more progressive. Progressivity using lump-sum transfers is obtained at a cost. Tax rate cuts would be more cost-effective – because of the double dividend effect discussed previously – but would induce less progressivity as tax rates are essentially proportional to income.

International Monetary Fund (IMF) (2019) projections suggest that while a carbon tax may be mildly regressive in some developed economies, this is not necessarily verified everywhere and the degree of regressivity depends on country-specific characteristics. In most developed countries, higher-income households tend to spend more on energy than lower-income households. However, energy expenditures make up a higher proportion of disposable income for the latter than for the former. Projection results indicate that for a $50 per tCO2e carbon tax in 2030 and with no accompanying measures, carbon taxes would be moderately regressive in China and the United States, and distribution-neutral in Canada. Obtained progressivity is the consequence of an increase in the budget share spent on electricity by lower-income households. Simulations further indicate that one third to one half of the burden of increased energy prices on households comes indirectly through higher general prices for consumer products.

In developing countries, however, results are mixed. IMF (2019) projections indicate that the carbon tax would be moderately progressive in India. Progressive impacts are also obtained in Indonesia (Yusuf and Resosudarmo, 2015), Viet Nam (Nurdianto and Resosudarmo, 2016), and Mexico (Renner, 2018). Regressive impacts are found in South Africa (Devarajan et al. 2011), Malaysia and the Philippines (Nurdianto and Resosudarmo, 2016), and Brazil (da Silva Freitas et al. 2016).

Distributional impacts of carbon pricing have challenged the political feasibility of swift and incisive climate policy and preclude its implementation. IMF (2021) shows that even if not regressive, a carbon tax would still reduce household welfare. Households must receive compensation, using for instance and as discussed previously part of carbon tax revenues. Redistributive policies could protect the purchasing power of lower-income households. Targeted cash transfers appear to be the least distortive although not the most cost-effective. Compensation measures would not only protect the most vulnerable households but may also, by acting as income buffers, facilitate the transition of energy workers towards greener jobs.

4.2.2 Carbon border tax

Using a static CGE model (GTAP-e), UNCTAD (2021) assesses the impact of the EU CBAM on developing countries. In line with Chepeliev et al. (2021), EU CBAM corresponds to a levy on the carbon content of imports (based on the carbon intensity of the country of origin) equal to the carbon price applied to a country's (e.g. European Union) production. Carbon prices of $44 and $88 are assessed using ad valorem equivalents, which may vary across sectors and countries. This approach implies that a carbon price increase from $44 to $88 doubles the CBAM uniformly across sectors and countries.

The imposition of higher carbon price leads to a decline in European Union and total CO2 emissions. However, a decline in domestic production in the European Union, as well as a decrease in exports and an increase in imports of the most energy-intensive products are also observed. Global exports of non-European Union countries increase, except for oil products. With the introduction of the CBAM, global real income falls further, with some regions benefiting and some incurring higher losses. The European Union reverses some of the economic losses generated by carbon price increases, while non-European Union countries as a group lose out. Observed gains in the European Union from the introduction of a CBAM are due to positive terms of trade effects compensating for allocative efficiency losses from rising tariffs. The gains and losses from the CBAM are, however, minor compared to the losses in real income that the European Union experiences with the increased domestic carbon price.

The global reduction of GHG emissions associated with higher carbon prices in the European Union and the introduction of a CBAM has distributional effects and a net-economic price of about 0.07 per cent of GDP for a carbon price of $44 and about 1.7 per cent for a carbon price of $44. Japan, Thailand, the Republic of Korea, the United States and some Latin American countries are expected to face income gains. Income effects are also positive for least developed counties and small island developing States which are exempted from the CBAM. Oceania (with Australia dominating that region), India, Serbia and Bosnia and Herzegovina, the Russian Federation, Ukraine, Saudi Arabia, South Africa and other countries in the Middle East, and to a lesser extent Brazil, Canada, China and Türkiye experience some losses.

Results further reveal a significant increase in European Union intraregional trade and a reduction of trade between the European Union and the rest of the world. Trade among non-European Union regions also increases. The CBAM acts as an increase in the external tariff of the European Union. It increases intra-bloc trade and diverts the trade of trading partners to other regions.

Using an input-output model, UNCTAD (2022) simulates the impact of a fall in demand of carbon intensive goods in the European Union due to the CBAM on the exports from LDCs. The overall effect of the CBAM on LDCs is negative even if they could benefit from some full exemption mechanism. This is due to the preponderant role played by carbon intensive intermediate inputs in LDCs export baskets.

Bellora and Fontagnié (2022) also present some results about impacts of the CBAM on third countries. The border mechanism leads to a positive terms of trade effect for the European Union.[53] It is stronger when the emissions of the exporter country are chosen as the reference. The most affected country in absolute and relative terms appears to be the United States of America. However, the United States would see a reduction in its trade deficit with the European Union. A similar pattern is obtained in relation to the European Union's trade with China or Japan, although absolute effects are on a smaller scale. India, on the other hand, is negatively affected, with an absolute deterioration of its trade balance driven by a drop in exports of intermediate goods. EFTA and the United Kingdom are the main beneficiaries of CBAM. They would benefit from a low carbon border adjustment once the carbon price they apply domestically is accounted for. This induces a relative cost advantage and an absolute improvement in their bilateral trade balance with the European Union.

4.2.3 Emissions trading

In addition to emissions reduction effects, Dechezleprêtre at al. (2018) also assess the effects of the EU ETS on several firm-level performance components in several European countries during the first two phases of the system. As compared to non-ETS control firms, in addition to higher revenue and fixed assets, ETS firms also increased employment and profits. EU ETS firms were not found to exit more frequently compared to uncovered firms. Results further point to heterogeneous effects across different sized firms. Even if the impact on revenue is statistically significant for all firms, it decreases in magnitude with firm size. Small companies would see their revenues rise by about 24 per cent on average. The impact on profits also varies with firm size. Smaller firms did not enjoy any statistically significant change in their profits and had to face a statistically significant decrease in their return on assets. These findings are consistent with larger firms that are able to pass carbon emissions costs onto their customers more systematically and face smaller abatement costs.

In principle carbon taxes and cap-and-trade systems can be designed to generate similar distributional effects among firms as shown in Goulder and Schein (2013). For instance, when allowances are auctioned, a cap-and-trade system and a carbon tax would have a similar impact on regulated firms. The latter would face a positive emission cost since the first unit of GHGs emitted. This may not necessarily be the case if allowances are freely distributed. In that case, some firms would be able to emit GHGs without incurring

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[53] This is consistent with the Gros (2009) and Balistreri et al. (2019) mechanism discussed in section 3.1.2.

any direct cost. The only cost faced would be in relation to the quantity of allowances they are granted. An equivalence could also be in principle obtained between a cap-and-trade system with freely allocated allowances and a carbon tax system that includes tradable tax exemptions for a predefined quantity of emissions.

4.3 CARBON LEAKAGE

Results based on ex ante analysis point to a relatively elevated risk of carbon leakage. They also suggest that carbon border taxes can help to contain such an effect. However, empirical evidence retrieved from past experiences shows that the case for carbon leakage may not in practice be that strong. The relocation of plants and firms is more likely to be driven by differences in production costs other than carbon. Moreover, tariffs and transportation costs can be higher than GHG emissions-related costs. Carbon pricing may also induce firms to opt for cleaner production technologies rather than relocating production. Firms may compensate for the loss in competitiveness due to carbon pricing by innovating in low-carbon products. Finally, firms may be able to pass part of their emission costs on to the final consumer without losing market share, thus reducing incentives to relocate their production.

Ex ante analysis

Several studies based on ex ante computable general equilibrium (CGE) models assessed the impact of various carbon pricing policies on carbon leakage. In their review, Carbone and Rivers (2017) find that leakage rates can vary between 10 per cent and 30 per cent.[54] As in the case of carbon pricing predicted effects on GHG emissions and activity, predictive results depend on model assumptions and the very components of the simulated emissions policy scenarios. Demailly and Quirion (2006) simulate the impact of the allocation of output-based emissions allowances in the EU ETS. Their results show that leakage would not occur, but also that emissions would not be curbed significantly. If technology spillovers are accounted for, Gerlagh and Kuik (2014) show that carbon leakage patterns can even be reverted with the European Union becoming a non-emissions haven. Bellora and Fontagnié (2022) simulated the efficiency of the CBAM versus free allowances in containing carbon leakage. They find that the implementation of the European NDCs, without free allowances, generates cumulated leakages amounting to 20.7 Gt of CO2 eq. over the period 2021–2040. High leakage reflects the more ambitious policy package simulated, i.e. the Fit for 55 package, relative to other ex-ante studies reviewed above. Free allowances are found to reduce these leakages by 30 per cent while the CBAM, without free allowances and independently of its design, reduces leakage by 40 per cent. A policy portfolio made of both free allowances and the CBAM reduces leakages by one third.

Ex post analysis

Naegele and Zaklan (2019) show that the emission cost imposed by the EU ETS is below 0.65 per cent of total material cost for 95 per cent of European manufacturing, while labour unit cost in Europe is about 10 to 30 times higher than in emerging countries. Thus, the cost impact of the European emissions policy remains quite moderate. The relocation of plants and firms is more likely to be driven by differences in production costs other than carbon. This pattern could only be reinforced if fixed relocation costs are accounted for. Relocation incentives due to carbon pricing would be further weakened if emissions policies combine costs and subsidies. For instance, within the EU ETS, covered manufacturing firms have been receiving substantial amounts of free emissions allowances, which have certainly contributed to limiting the leakage risk as shown in Schmidt and Heitzig (2014). Carbon pricing may also induce firms

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[54] Based on a meta-analysis of earlier studies, Branger and Quirion (2014a) find an average leakage rate of 12 per cent.

to opt for cleaner production technologies rather than relocating production. Firms may compensate for the loss in competitiveness due to carbon pricing by innovating in low-carbon products. As predicted by the Porter hypothesis, this would increase their productivity (Porter and Van der Linde 1995; Calel and Dechezleprêtre, 2016). Innovation can be further incentivized if governments set up R&D subsidies programmes in conjunction with carbon pricing (Acemoglu et al. 2012, Aghion et al. 2016).

Several studies also tested the hypothesis of the pollution haven effect in the United States of America. Estimates essentially concern the link between net trade flows and the stringency of pollution control measures, as defined in the Pollution Abatement Cost (PAC). Empirical investigations are mostly based on survey data of United States manufacturers. Empirical results offer a mixed picture. In a review of early studies, Jaffe (1995) concludes that the United States environmental policy has not systematically affected trade flows, suggesting that environmental expenditures imposed by the new regulation have not been large enough to induce relocation. However, Dechezleprêtre and Sato (2017) review more recent contributions and conclude that despite a limited induced burden on firms, firms may have reacted to it in line with the pollution haven hypothesis.

Some studies have attempted to assess the impact of the Kyoto Protocol. Based on a gravity empirical framework, Aichele and Felbermayr (2015) find that the carbon content of sector-level bilateral trade appears to be significantly impacted by a country’s ratification of the Protocol. Ratification is associated with a 7 per cent reduction in domestic emissions but an increase of about 14 per cent in the share of imported embodied carbon emissions over domestic emissions. Embodied carbon imports from non-committed countries increase by around 8 per cent and the emission intensity of their imports by about 3 per cent. The authors conclude that the Kyoto Protocol induced some carbon leakage. However, impact channels are not identified, and leakage may have been the consequence of factors other than the Kyoto Protocol commitments. For instance, Branger and Quirion (2014b) point to the fact that China’s joining the WTO coincided with the ratification of the Kyoto Protocol by most countries imposing some environmental regulation.

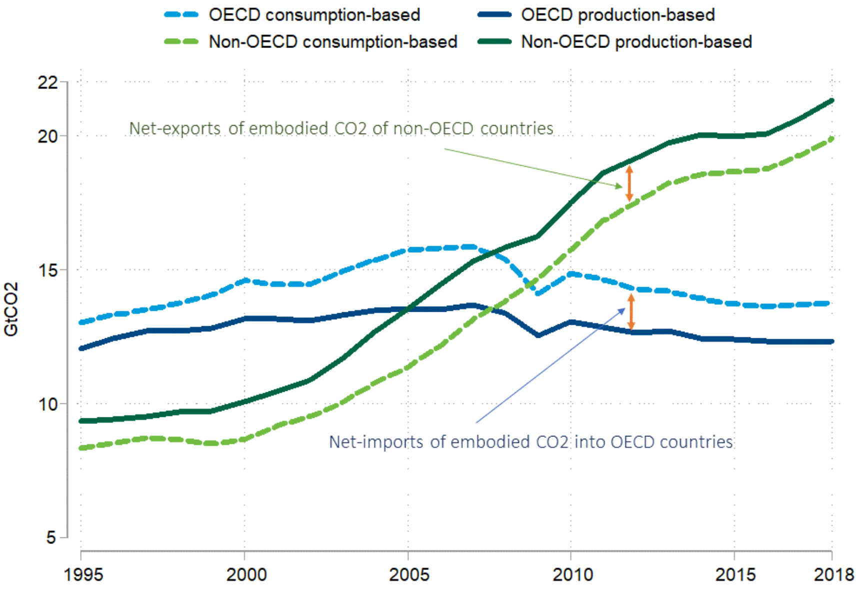
Some studies estimate the extent of carbon leakage in the EU ETS through different channels. They suggest that ex ante modelling exercises may have overestimated leakage effects. Based on a survey of multinational firms, Dechezleprêtre et al. (2014) find no evidence of relocation of emissions-intensive processes within multinational firms due to the EU ETS. Koch and Basse Mama (2016) use firm-level data on foreign direct investment (FDI) by German multinational companies to investigate the investment channel. They find no evidence that the EU ETS induced relocation of production through an increase in outbound FDI. Impact assessments at the sectoral level based on trade flows reveal no significant leakage effects of the EU ETS. For instance, Sartor (2013) finds no evidence of carbon leakage in the aluminium sector. Branger et al. (2016) reach similar conclusions for both the cement and steel sectors. Naegele and Zaklan (2019) combine data from the GTAP global trade data set with input-output information and administrative data from the EU ETS to estimate the effect of the EU ETS on trade flows in manufactured goods. Various policy stringency measures are considered and both direct and indirect emission costs from electricity use are accounted for. Several specifications are tested including non-linearities in the stringency effects across sectors. No evidence of carbon leakage is found. The absence of trade effects suggests relocation incentives induced by rising emission costs are weak relative to costs associated with relocation. For instance, tariffs and transportation costs are much higher than CO2-related costs. This is certainly associated with market power that allows firms to pass part of their emission costs on to the final consumer without losing market share.

4.4 GLOBAL VALUE CHAINS

The fragmentation of production and the development of global value chains (GVCs) whose complexity has been steadily increasing over the last three decades have played a key role in the geographical distribution of GHG emissions. To be able to identify climate policy as the main cause for leakage, it is necessary to account for trade-embodied GHG emissions as precisely as possible. As discussed in Hertwich (2020), participation in GVCs would need to be taken into consideration when framing carbon border policies. The latter, assuming that they can be imposed legally, may offer protection from unfair foreign competition for final goods but could also harm both domestic production and exports that rely heavily on imported inputs.

Together with a relative shift towards a service economy in many high income countries and with the overall fall of international trade costs, the globalization of production chains strongly contributed to turn many OECD countries into net importers and non-OECD countries into net exporters of trade-embodied GHG emissions, as shown in figure 4.[55] In other words, the fact that countries are net importers of trade-embodied emissions does not necessarily imply that this is the consequence of differences in environmental regulations giving rise to different carbon prices.

Figure 4 Production-based and consumption-based CO2 emitted by OECD and non-OECD countries



Source: OECD.Stat at https://www.oecd.org/sti/ind/carbondioxideemissionsembodiedininternationaltrade.htm.

Contrasting effects act simultaneously on the GVCs–GHGs nexus, implying that GVC participation has differentiated impacts on GHG emissions across countries and sectors. Two opposing forces determine the impact of participation in GVCs on GHG emissions.[56] On the one hand, participation in GVCs may induce a scale effect that induces more energy consumption, resulting a higher level of per capita GHG

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[55] Note that Canada, the Republic of Korea, Poland, Türkiye, Czechia, the Netherlands and Denmark were net exporters in 2018 while among non-OECD economies, Argentina and Brazil were net importers as described in Yamano and Guilhoto (2020).

[56] These forces are comparable to those defining the relationship between trade and GHG emissions. See WTO (2022) for an extensive discussion.

emissions. A composition effect may also be enacted, reorienting domestic production towards more carbon-intensive industries. On the other hand, participation in GVCs may induce a competition effect and a technology spillover effect, both of which could lead to a reduction in the carbon intensity of production. As discussed in Wang et al. (2019), scale and composition effects are likely to prevail over competition and technology spillover effects in the early stages of participation in GVCs. The reverse relationship can be observed at later stages of participation in GVCs. Thus, in a cross-country analysis this may give rise to an inverted U-relationship between participation in GVCs and GHG emissions.

Using a multi-regional input-output data set with production emissions information,[57] Hertwich (2020) provides estimates of GHG emissions associated with the production of imports used to produce exported products. The most imported products used for export production are petroleum, iron and steel, chemicals, electronics and shipping. Carbon in transit increased almost threefold from 1995 to 2016, representing 10 per cent of global emissions.[58] The incidence of carbon in transit is found to be the highest for chemicals, machinery and equipment, motor vehicles, and electronics.

Duan et al. (2021) provide an empirical test of the pollution haven hypothesis using a multi-country input-output model and applying a structural decomposition analysis. This approach allows them to take full account of global value chains. They calculate emission intensities using bilateral value-added trade data and disentangle the trade composition effect from the technology effect. Their results suggest that the per capita income gap between importing and exporting countries correlates positively with more pollution-intensive exports expressed in value added terms. This result supports the existence of a pollution haven effect in trade when expressed in value added terms. It suggests that high emissions production stages were moved to low-income countries. These results are in contrast with those of most export studies reviewed in the previous section, which used standard gross trade data unable to reflect the operating of global value chains.

Wang et al. (2022) investigate the dynamic relationships between participation in GVCs, GHG emissions, and economic growth. Their analysis is based on advanced panel techniques applied to data for 63 countries and regions from 2005 to 2015. Their findings suggest that GVC participation is associated with an increase in per capita GDP and a reduction in per capita CO2 emissions in the long run. Moreover, the participation of GVCs in carbon-intensive industries explains a sizeable proportion of the variation in per capita CO2 emissions. Among high value-added industries, participation in GVCs explains a sizeable proportion of the variation in per capita GDP.

4.5 CARBON PRICES

Overall, current observed carbon prices are still low compared to the levels that need to be reached to meet the 1.5 °C objective. As mentioned below, to reach that objective the carbon price should be at least €60/tCO2e (or about $ 60/ tCO2e) by 2030. In 2021, the observed median carbon price was about $24/tCO2e.

Some price convergence has occurred over the last decade across carbon tax schemes. A move towards international linkage of carbon markets has recently been initiated[59] and some price convergence has been observed across carbon pricing instruments.[60] This is illustrated in figure 5 which graphs prices

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[57] The version 3.6 of the EXIOBASE MRIO database. Details are provided in Stadler et al. (2018).

[58] According to estimates by Sims and Schaeffer (2014), this share is close to that of emissions from road transport.

[59] For instance, since 1 January 2020, a linkage between the Swiss ETS and the EU ETS came into force. Covered entities in the Swiss ETS can use allowances from the EU ETS for compliance, and vice versa.

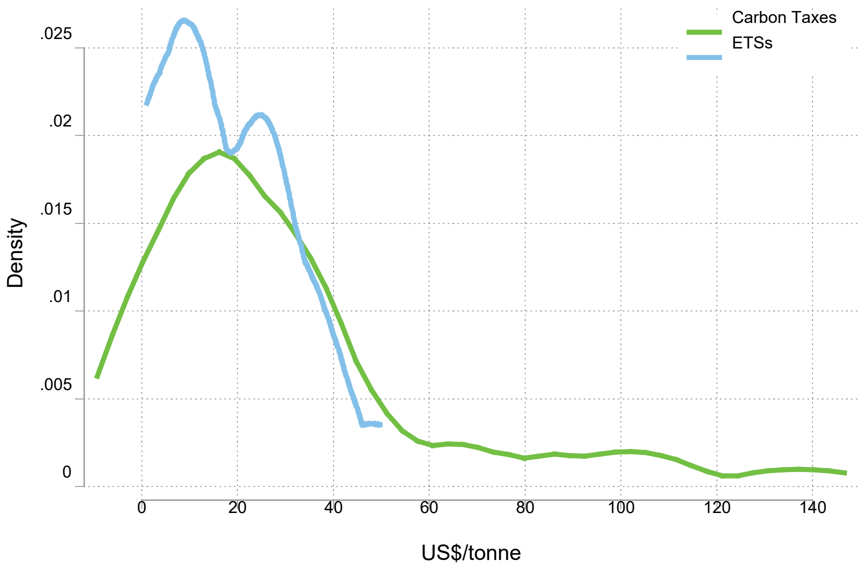
[60] A precise appreciation of convergence patterns would have to also consider programme scopes and calculation methods in addition to effective nominal prices.

distribution in carbon taxes schemes and ETSs. The number of programmes represented jumped from 17 in 2010 to 65 a decade later. While three fourths of them were carbon taxes in 2010, that share fell to less than 60 per cent in 2021.

Between 2010 and 2021 an increasing share of carbon tax programmes imposed carbon prices around $20/tCO2e. This pattern of relative convergence emerged with the extension of the set of countries implementing tax programmes and imposing prices predominantly around that level. However, carbon tax programmes implemented in Switzerland, Sweden and Liechtenstein imposed carbon prices that were above $100/tCO2e in 2021.

The significant increase in the number of ETS programmes established since 2010 may not have contributed to price convergence across ETSs, as reflected by the emergence of a twin-peaked distribution in 2021. This is confirmed by dynamic factor analysis applied to the various ETS price series. Using monthly dollar carbon prices of 13 major ETSs[61] observed from January 2009 to March 2022, Fugazza and Neto (2022) find no evidence of integration among the various systems and conclude a lack of systemic price convergence. However, their results also reveal that once idiosyncratic disturbances are accounted for, a carbon price emerges that is consistent with all ETS markets structural equilibrium conditions. This revealed global equilibrium carbon price has varied between 2.05 to 16.1 $/tCO2e. This price range is long way from the range of 50-100 $/tCO2e suggested for instance in the High-Level Commission on Carbon Pricing report published in 2017 (Stern and Stiglitz et al., 2017) to achieve global climate ambitions by the end of the decade.

Figure 5 Carbon prices ($/tCO2e) distribution: taxes versus ETS, 2021



Source: Author's own elaboration based on World Bank Carbon Pricing Dashboard.

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[61] Data were retrieved from the ICAP database https://icapcarbonaction.com/en/ets-prices. Twenty ETS are covered. However, for seven of them, too many values were missing and made their exploitation difficult.

Statistics reported in table 6 reveal prices are on average higher for carbon tax programmes than for ETSs. This is also verified for median values. We also observe that price gaps across programme types decreased substantially between 2010 and 2021. This is clearly the result of increasing prices in ETS programmes. Such a trend may have not been observed without some rationalization in the management of ETS programmes. In the case of the EU ETS for instance the number of permits allocated has been decreasing over time. At first the European Union allocated "too many" permits to allow firms to try out the system and exchange at very low cost. It then decreased the number of permits on the market, which led to an increase in their price. This trend is expected to continue in the coming years as the European Union objective is to reduce allowances by 2.2 per cent a year to obtain a total reduction of 43 per cent in emissions in 2030 (compared to 2005) and achieve carbon neutrality in 2050.[62] Additional statistics show that dispersion, as measured by standard deviation, is higher among carbon tax programmes than ETSs. However, as figure 5 also shows, dispersion has been steadily increasing among ETS programmes.

Table 6 Prices in implemented carbon pricing initiatives selected

YEAR	TYPE	MEAN	MEDIAN	STD	MAX	MIN	#
2021	Tax	29.96	23.87	31.48	137.24	.078	36
	ETS	17.20	17.94	13.82	49.78	1.12	29
2015	Tax	26.49	20.05	31.25	129.81	.011	20
	ETS	10.59	6.84	10.33	37.51	2.05	18
2010	Tax	30.79	20.20	38.43	145.48	.084	13
	ETS	11.72	13.66	6.58	17.26	2.3	4

Source: Author's own elaboration based on the World Bank Carbon Pricing Dashboard.

Based on previous data, a general observation could be that carbon prices are still too low with respect to price levels consistent with COP 26 objectives. Aiming to limit the rise in global temperature to 1.5 °C would require complete decarbonization by 2060 according to recent estimates by Kaufman et al. (2020). To reach that objective, the carbon price should be at least €60/tCO2e (equivalent to about $60/ tCO2e) by 2030. Comparable earlier estimates by the High-Level Commission on Carbon Pricing (Stern and Stiglitz et al. 2017) pointed to a price between $50 and $100/tCO2e. The OECD has computed a carbon pricing score indicating the current gap between observed carbon prices across different markets and programmes in place in 44 OECD and G20 countries and the reference threshold prices estimated by Kaufman et al. (2020).

Figure 6 reproduces such scores for the €60/tCO2e (equivalent to about $60-$65/ tCO2e) benchmark. As discussed in OECD (2021) countries made some progress between 2015 and 2018 but are still showing carbon prices too low to reach the 1.5 °C maximum temperature increase objective.

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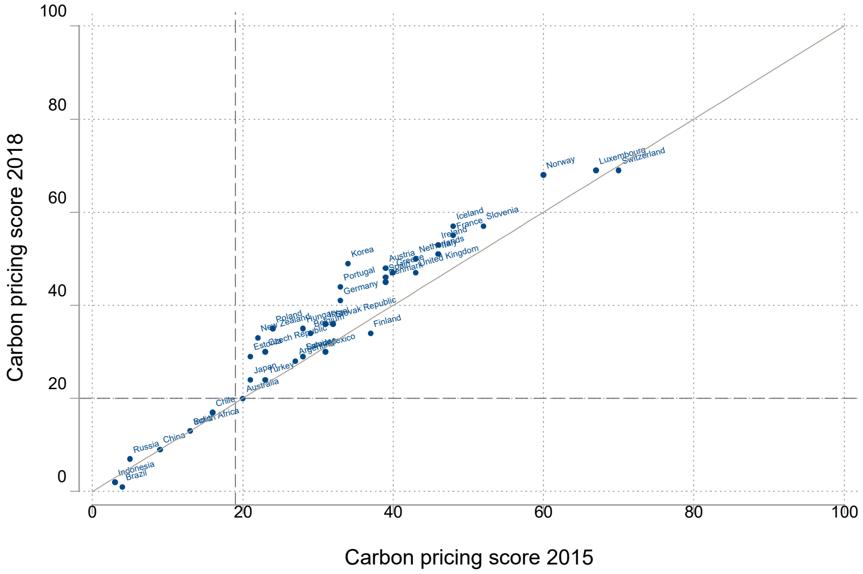
[62] Additional information is provided at https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/revision-phase-4-2021-2030_en

Figure 6 OECD Carbon price score (€60/tCO2e reference cost)



Source: OECD.stats, Effective carbon rates available at https://stats.oecd.org/Index.aspx?DataSetCode=ECR#.

Note 1: The reference carbon cost is €60/ tCO2e. A carbon pricing score of 100 per cent shows that a country prices all carbon emissions at the carbon cost estimate or higher and a carbon pricing score of 0 per cent shows that a country does not price any carbon emissions.

Note 2: Observations below the 45-degree line / diagonal correspond to falling prices between 2015 and 2018. The reverse is true for observations above that line. Dashed lines represent sample means in 2015 and 2018, respectively.


CO₂
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CO₂
CO₂

Chapter 5

Non-market-based approaches to carbon pricing

This chapter reviews major non-market approaches to carbon pricing. As discussed in chapter 2, a non-market approach can be any approach, provided it does not generate some tradable units of emissions. Non-market mechanisms include fiscal measures, such as putting a pre-determined price on carbon or applying taxes to discourage emissions. Non-market approaches can also be implemented in the context of cooperative actions between countries to achieve mitigation and adaptation and possibly other sustainable development objectives such as poverty reduction.

5.1 RESULTS-BASED CLIMATE FINANCING

Results-based financing (RBF) instruments can be specifically dedicated to climate-related projects. RBF is expected to have a positive effect on the economic efficiency of public procurement. RBF instruments applied to the issue of climate change may help address the existing and still critical environmental funding gap.[63] The success of RBF applied to climate change relies heavily on the design of the incentive scheme and may face serious implementation challenges. Two classes of RBF instruments applied to climate change have been implemented so far, namely results-based climate finance (RBCF) and environmental impact bonds (EIB).

Results-based climate finance[64] adopts an RBF mechanism in which payments are conditioned on climate mitigation (or adaptation) results. It mostly relies on carbon finance projects which involve contracts to purchase emissions reductions, such as certified emission reduction (CER) credits. RBCF results are in general delivered and verified by an independent entity.[65]

RBCF is expected to align the objectives of the donor or investor with those of the recipient of funds (the principal-agent mechanism). Consequently, the financial risk of non-delivery of results is borne by the agent and not by the principal as would be the case in standard credit schemes. Asymmetry of information and its potentially damaging effects can thus be reduced, and the effectiveness and cost efficiency of support improved. RBCF projects can also contribute effectively to structural change and can thus be used to achieve long-term mitigation (and adaptation) objectives. In this context, the use of RBCF in combination with other financial instruments, such as up-front grants, can offer a solid complement or even alternative to carbon pricing schemes currently implemented, and in particular offset programmes. Various RBCF programmes aim not only to purchase verified reductions in GHG emissions but also to reduce poverty, improve access to clean energy and offer health and community benefits.[66]

5.2 ENVIRONMENTAL IMPACT BONDS

Environmental impact bonds (EIBs) come under the broad umbrella of “green” bonds. They are outcomes-based climate-specific contracts.[67] A major difference with RBCF schemes is the active involvement of the private sector. Private funding from investors is used to cover needs in up-front capital for a provider to set up and deliver a climate-related service. EIBs have a similar structure to traditional bonds, where

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[63] Recent estimates by Deutz et al. (2020) suggest that globally, $722 to $967 billion is needed annually for environmental conservation alone, but the current allocation stands at $124 billion a year.

[64] See Escalante and Orrego (2021) for an extensive discussion and description of some existing RCBF programmes and projects.

[65] Results can refer to emissions reductions expressed in tonnes of carbon dioxide equivalent (tCO2e) but can also be based on disbursement-linked indicators (e.g., megawatt hours of installed renewable energy (RE) capacity, and number of cook stoves distributed) as well as qualitative disbursement-linked indicators (e.g., the implementation of a policy or the strengthening of MRV capacity).

[66] See World Bank (2017) for a comprehensive assessment of early RCBF programmes.

[67] The concept and the associated financial instrument originated in the social services sector with social impact bonds. Brand et al. (2021) offer a critical review of existing EIB programmes and some possible improvements.

principal is borrowed by stakeholders/beneficiaries with the engagement of repayment to investors, with interest, over time. However, while traditional bonds are repaid with general revenues from the issuer not necessarily related to the financing activity, the repayment of EIBs is tied to the success of the intervention and revenue generated (and/or cost savings realized) within the climate-related project. EIBs can also include penalties tied to the non-achievement of outcomes. The investor receives an amount for risk coverage in the event of underperformance. If the outcome is successful, the investor receives benefit/ profit share, along with other investors as well as contractors. In other words, the incentivized agent is not the implementing agency but rather the investor providing the up-front funding. This instrument can also in principle combine climate goals with social, resilience and economic objectives. Even though EIB programmes implemented so far[68] have not necessarily included emissions reduction objectives, at least not as their primary objective, they may, like RBCF projects, represent a more cost-effective and efficient alternative to offset programmes.

5.3 INTERNAL PRICING

Companies can voluntarily set themselves a carbon price to internalize the economic cost of their GHG emissions.[69] Some companies use the carbon price they face in mandatory initiatives as a basis for their internal carbon price. Some companies also adopt a range of carbon prices internally to account for possible differences in prices across jurisdictions and/or to factor in future increases in mandatory carbon prices. This internal carbon pricing can be used as tool to support a company's decarbonization strategy. But it can also represent an effective risk management tool, allowing companies to anticipate and assimilate regulatory climate policies as part of their global strategies. Voluntary internal carbon pricing should then systemically complement governments' GHGs emissions reduction policies to which companies are subject. The introduction of an internal carbon pricing system requires in the first place calculating the company's direct and indirect GHG emissions. GHG emissions are categorized into three groups or 'scopes' by the most widely used international accounting tool, the GHG Protocol.[70] Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain. Note that taking the Scope 3 emissions into account may require information to be collected beyond firms' boundaries. Companies must not only be able to record such information with sufficient accuracy, but they should also have decisional leverage to reduce the emission factors involved. Details of scope content are shown in table 7.

Companies adopting internal carbon pricing have so far opted for either an internal carbon tax or a shadow price. The internal carbon tax is a tax that companies decide to apply to their operations. The tax consists of adding a cost relating to generated GHG emissions to the operational costs. The introduction of an internal carbon tax implies transfers of actual funds within the company. These are generally assigned to internal decarbonization policies (e.g. purchase of offset credits externally or funding of internal projects related to emissions reduction). The shadow carbon price approach consists in applying a carbon price, decided by the company, to GHG emissions to be generated within each investment decision (e.g. R&D, infrastructure or financial assets). The aim is to assess the impact of a carbon price on the company's strategy and on the calculation of the internal rate of return (IRR) on their investments. However, unlike an internal carbon tax, this shadow pricing scheme does not imply any financial transaction. It simply

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[68] The first EIB was the DC Water Environmental Impact Bond, created in 2016 by DC Water with Quantified Ventures to finance the implementation of green infrastructure. Another successful case is the Atlanta Environmental Impact Bond, the first publicly offered EIB (2019).

[69] See IC4E and EPE (2016) for a large set of practical implementation examples.

[70] The Greenhouse Gas Protocol was jointly convened in 1998 by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) and was first established in 2001.

introduces an additional criterion into business activities management and is expected to affect strategic decisions made by the company. Shadow carbon price schemes can thus enhance the profitability of those projects that are most compatible with the transition to a low-carbon economy.

Table 7 GHG scopes in the GHG Protocol

Scope 1	Scope 2	Scope 3
Fuel combustion	Purchased electricity, heat and steam	Purchased goods and services
Company vehicles		Business travel
Fugitive emissions		Employee commuting
		Waste disposal
		Use of sold products
		Transportation and distribution (up- and downstream)
		Investments
		Leased assets and franchises

Source: Author's own elaboration based on https://ghgprotocol.org/.

Internal pricing based on an internal tax would be perfectly compatible with voluntary offset programmes. However, several issues may arise when considering consistency with mandatory external carbon pricing. From a company's point of view, the level of tax and/or the price of carbon chosen may have to take account of external regulations to avoid too restrictive budgetary choices. For instance, what would be the most appropriate strategy if a carbon tax has already been introduced by the country's government? The government would face a symmetric issue . Some fiscal deductions may apply if firms prove they are able to effectively tax carbon emissions within internal carbon pricing schemes. Moreover, if firms with internationally organized production are able to price all emissions along their production chain, governments may want to exempt those firms from the application of any carbon border adjustment scheme. These issues are likely to become more acute as new countries introduce carbon pricing and as pricing levels make internal and external carbon-related charges more sensitive.

A recent Carbon Disclosure Project (2021) survey[71] reveals that in 2020, 90 per cent of companies with an internal carbon price disclosed that it applied to their direct emissions (scope 1). The survey further indicates shadow pricing is the most common type of internal carbon price. Half of the responding companies disclosed the use of a shadow price in 2020. Shadow pricing has consistently been the most common type of price utilized. Median prices are about $27/tCO2e whether we consider shadow or implicit prices. Pricing schemes implying internal financial flows directly related to GHG emissions impose much lower rates. Indeed, the median internal fee stands at $18/tCO2e. While shadow prices are more in line with median values of carbon prices in tax programmes, internal fees are comparable to median price values emerging from ETS programmes.

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[71] The Carbon Disclosure Project is the largest repository of information since 2014 about carbon pricing within companies. In 2020, carbon pricing data from over 5,900 companies were collected and analysed in the Carbon Disclosure Project (2021) report.

5.4 SUBSIDIES AND CERTIFICATION

GHG emissions can also be implicitly priced through other policy instruments such as the removal of fossil fuel subsidies, support for renewable energy (e.g. Renewable Portfolio Standards), and energy efficiency certificate trading or standards.[72]

The efficiency of a carbon tax relative to fuel regulation has received much attention and has been shown convincingly in several studies.[73] Taxes on emissions, whether explicit or implicit, create incentives to adopt more fuel-efficient technologies and equipment. In the case of transportation, for instance, this translates into the anticipated acquisition by consumers of less polluting vehicles and/or lower overall driving distances. A fuel-efficiency standard, under which the fleet of cars produced has to meet minimum fuel economy standards, also incentivizes the anticipated purchase of more fuel-efficient vehicles. However, a rebound effect may be observed, where driving distances increase due to improved fuel efficiency. The standard does not apply to vehicles already in circulation, so the market value of these vehicles may increase, and their replacement may be delayed. Standards may eventually prove less cost-effective than emissions taxes for achieving given emissions reductions. Furthermore, standards are known to limit the incentives to invest in the development of greener technologies as they are established through regulation (whereas carbon pricing gives continuous incentives to develop new technology that lower abatement costs).[74]

Besides removing fossil fuel subsidies, providing financial support to activities that are in direct competition with fossil fuels can help reduce pollution effectively. An ideal approach would be to transfer these subsidies from fossil fuels to renewables. This approach could ease concerns about the necessity to raise funds to finance subsidy programmes. Renewable portfolio standards (RPSs) are policies commonly implemented in several European countries and in various states of the United States of America. RPS programmes are essentially a subsidy programme augmented by specific regulations. These could for instance impose that a share of the electricity sold within the area of jurisdiction must come from a designated renewable source. Electricity prices are not expected to rise as much as when a tax is imposed, and firms and individuals may refrain from investing in energy efficiency to reduce consumption. Some rebound effects may even be observed. Existing evidence suggest that a carbon tax is likely to be more cost-effective in reducing GHG emissions.[75]

As shown in previous chapters, carbon taxes can have strong trade effects as they affect production costs and potentially international competitiveness. The trade effects of either energy efficiency standards or subsidies is less clear cut. If energy efficiency is signalled by some form of label on goods produced using energy-efficient sources, these goods may benefit from some increase in demand on international markets. The resulting positive demand shock may translate into an increase in exports of those goods.

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[72] Approaches adopted by either the IMO to regulate CO2 emissions in maritime transport or the EU to regulate its internal transport sector belong to this last category of policy instruments.

[73] Anderson and Sallee (2016) provide a review of that literature.

[74] For instance, Jacobsen (2013) estimates that the cost of fuel economy standards per tonne of CO2 avoided is about three times the cost of a comparable gasoline tax.

[75] Estimates in Reguant (2019) suggest that the cost of reducing carbon emissions by 10 per cent in the electricity sector was more than six times higher with an RPS programme than with a carbon tax applied to fuels used to generate electricity.


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Chapter 6

National and international policies to improve cost-effectiveness of carbon pricing

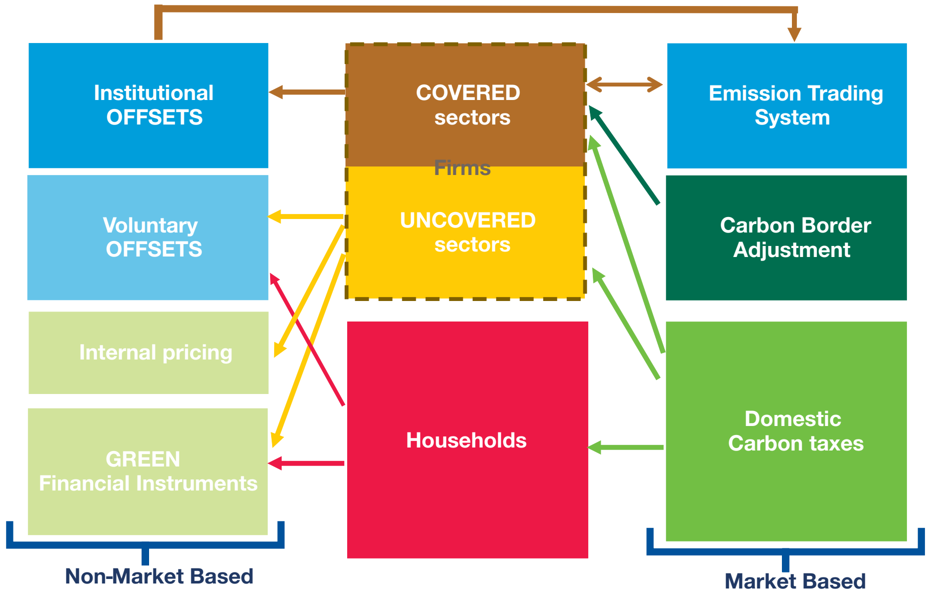
Carbon pricing, in particular carbon taxes and carbon emissions trading, are a core element of government policies to combat global warming. However, as pointed out in previous chapters, such policies are often difficult to implement. Taxes may face strong opposition both from consumers and producers even if they are efficient instrument for reducing GHG emissions with respect to any alternative non-market policy instrument (Metcalf 2021). Emissions trading systems require constant monitoring and evaluation by their regulatory bodies to avoid high volatility in carbon prices. Several mechanisms underlying the impacts of unilateral environmental policies and their possible negative consequences for the implementing countries have been identified and should be accounted for. Reconciling national action plans with their potential global spillover effects, as reflected in the elevated risk of emissions (production) leakage, remains the core issue and a major determinant of cost-effectiveness.

To cost-effectively meet the globally agreed climate target, five areas of improvement can be highlighted: complementarity of policy design and policy instruments, direct involvement of firms in mitigation efforts, political acceptability, and international coordination and cooperation.

6.1 COMPLEMENTARITY OF POLICY DESIGN AND POLICY INSTRUMENTS

Chapter 2 described the relatively wide range of existing carbon pricing instruments. These are illustrated in figure 7, which highlights the complexity of determining the true impact of the various schemes, often implemented simultaneously, on GHG emissions. Smart policy design, including a large measure of coordination, might be necessary to solve a policy conundrum that could result in poor environmental effects and an overall negative economic impact possibly tinted with protectionism.

Figure 7 Carbon pricing instruments



Source: Author's own elaboration based on insights from chapters 2 and 3.

As discussed previously, ETSs and carbon taxes are the carbon pricing instruments predominantly used by governments. They are also increasingly being used in complementary ways, with features of both types often combined to form hybrid approaches to carbon pricing. For instance, Austria implemented a carbon levy of €30/tCO2e in July 2022 under its national ETS as part of broader fiscal reforms in the

Eco-Social Tax Reform Act 2022. The national ETS covers mainly heating and transportation emissions still not covered by the EU ETS. Some other initiatives allow the use of credits from offset mechanisms as flexibility for compliance. This approach may be abandoned, however, due to the potentially depressive effect credits from offsets may have on ETS carbon prices. This is for instance the case of the EU ETS. As of Phase IV (2021-2030) credit for emissions reductions outside the EU ETS is no longer allowed.[76]

A general observation, however, that can be retrieved from the empirical evidence reviewed in chapter 4 and discussed in Greene (2021) is that carbon pricing has so far had a limited impact on emissions. This could suggest that policies in place have not been incisive enough to significantly curb GHG emissions (leading to low levels of carbon price), and/or that their implementation has been hindered by a lack of coordination within and among countries and regions.

Carbon pricing schemes and scope

The scope of implemented carbon pricing initiatives on carbon pricing remains limited. In 2022, these initiatives cover 23.11 per cent of global GHG emissions (World Bank, 2022). In the European Union, which is responsible for 6 per cent of global GHG emissions, the ETS is expected to cover about half of the area's emissions. In China, the largest emitter of GHGs with almost one fourth of global GHG emissions, the national ETS should cover over 30 per cent of the country's total GHG emissions. In the United States of America, the second largest emitters of GHGs with more than 11 per cent of total emissions, carbon pricing schemes cover about 10 per cent of the country's GHG emissions. Sectoral coverage of existing carbon pricing schemes may need to be significantly enlarged to increase the impact of carbon pricing on emissions.

Increasing sectoral coverage is envisioned for instance by the European Union in its "Fit-for-55 package", which aims to include, for instance, the maritime sector in the EU ETS.[77] Other adjustment margins can be considered in the functioning of ETSs. Besides sectoral coverage, the functioning and institutional governance of an ETS can also be reformed to make the scheme more impactful in terms of GHG emissions. As discussed previously, free allowances can disincentivize industries' decarbonization efforts as they may act as a production and possibly as an export subsidy. This explains the European Union's intention to phase out free allocation of emission allowances to aviation and to the sectors that are to be covered by the carbon border adjustment mechanism.

To curb GHG emissions effectively, carbon taxation may require broader tax bases or higher tax rates. Austria's clear objective of reducing GHG emissions is reflected in its Eco-Social Tax Reform Act 2022, which includes plans to increase its carbon tax on transport and heating from €30/tCO2e to €35/tCO2e in 2023, to €45 in 2024 and to €55 in 2025. However, putting a price on carbon – especially if the latter is imposed exogenously – necessarily increases production costs and may have negative repercussions on domestic production, exports and labour market conditions. To avoid possible competitiveness downsides of carbon taxation, governments often associate some direct or indirect rebates as part of a broader tax reform. Such complementary policies may cause some sort of rebound effect and may help explain the relatively minimal impact on emissions.

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[76] Besides the need to curb oversupply to preserve the cost-efficiency of the EU ETS, the use of offsets has become controversial. Results in Cames et al. (2016) suggest only 2 per cent of the projects implemented as of 2016 and 7 per cent of potential CER supply during the 2013-2020 period have a high likelihood of ensuring that emissions reductions are additional and are not over-estimated.

[77] The European Union's "Fit for 55" package includes the necessary climate policy revisions to align with the new climate ambitions, committing to cutting emissions by at least 55 per cent by 2030 and reach emissions neutrality by 2050.

The recycling of revenues generated by carbon pricing is crucial in determining both the cost-effectiveness of carbon pricing schemes and their degree of progressivity. As shown in chapter 4, lump-sum transfers to individuals would support a redistributive policy objective (the so-called carbon tax and dividend strategy) while proper fiscal reform or redistribution to firms (the so-called double dividend strategy) would support cost-effectiveness. In Argentina for instance, a carbon tax, implemented in 2018, is levied on most liquid fuels but also on some solid products. The corresponding revenues are distributed via several distributive systems such as the Federal Revenue Distribution System, the social security system, the Transport Infrastructure Trust, or the National Housing Fund (FONAVI). The government thus signals some redistributive objectives even though progressivity may not necessarily be observed. In the case of Uruguay, political objectives appear to be more oriented towards emissions efficiency. The proceeds of the carbon tax on petrol, revised in 2022, are partially allocated to the financing of policies that promote GHG emissions reduction, sustainable transportation, and adaptation to climate change.

As discussed in chapter 4, no systematic trade-off exists between cost-effectiveness and distributional fairness among households and between households and firms. The wide range of input parameters and outcomes that reflect the specific socioeconomic circumstances of each country points to the complexity in designing and implementing a carbon pricing policy package. Moreover, the recycling of carbon pricing revenues is likely to be a sensitive political issue in most circumstances, and thus merits all due attention and transparency.

Border adjustment

The lack of international coordination has also resulted in the use of policy instruments aimed at reducing competitiveness gaps induced by carbon pricing schemes. As discussed in chapters 3 and 4, domestic carbon pricing schemes can negatively affect the international competitiveness of firms in the implementing country and cause carbon leakage. The EU CBAM, to be progressively implemented starting in 2023, may be an effective answer to these concerns. However, it may also be seen as a protectionist measure and give rise to retaliation by trade partners. Consequently, such measures may further compromise internationally coordinated climate policies and even make the political context for effective international cooperation more precarious. As underlined in FGCEE (2021), the EU CBAM should not be used as an instrument of trade, competition, or industrial policy, but as an environmental policy instrument. Its main objective should be to reduce global carbon emissions, not to preserve, or even increase, the competitiveness of European industries. Moreover, the scheme should concern imports exclusively. The implementation of a symmetric scheme, with a rebate equivalent to the domestic carbon tax granted to producers, should also be avoided. In addition to exposing the border adjustment scheme to legal issues in the context of the WTO,[78] a symmetric scheme would closely resemble a domestic consumption tax[79] in the presence of a cap-and-trade system such as the EU ETS. Domestic producers and foreign producers would then pay the carbon tax when selling their products to domestic consumers, while no producer (domestic or foreign) would pay the tax when selling the same products to foreign consumers. The carbon tax is expected to be passed on to domestic consumers exclusively. Hence, domestic consumers, who would be the ones bearing most of the burden, may not perceive it as a fair policy instrument to combat global warming.

6.2 DIRECT INVOLVEMENT OF FIRMS IN MITIGATION EFFORTS

Firms are often the economic agents that are the most reactive to climate policy as they are at the core of such a policy and their survival depends on their resilience.

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[78] See for instance WTO (2022) and Bellora and Fontagné (2022) for an extensive discussion.

[79] Elliott et al. (2010) define the precise conditions for perfect equivalence.

Greening firm's practices and investment

Firms can adjust to regulatory costs associated with environmental policy by modifying their input choices and their decisions to abate emissions. They can also adjust by revising their decisions in terms of technology adoption. Finally, and more radically, they can decide whether to enter a market in the first place. As shown in Finkelstein Shapiro and Metcalf (2021), the last two considerations, which constitute the extensive margin of firms' adjustment, are decisive in containing the adverse labour market effects of carbon taxes, along with expansion in output and consumption. Most climate policies do not adequately address market failures operating at the micro level. This may prevent firms from adopting sustainable management practices or carbon-efficient technology. Decarbonization imposes a growing need for massive upgrading of firms' capabilities, and this may exacerbate the productivity gap between firms in developed and developing countries. Firms will only embrace governments' mitigation efforts if carbon pricing is associated with tailor-made support programmes. In other words, vertical as well as horizontal distributional programmes should also be implemented to obtain firms' full adhesion. To avoid deepening the gap between firms in developed and developing countries, international transfer programmes should also include some distributional component in their support approach. This would imply for instance dedicating part of the transfer programmes to technological upgrade and adoption favouring less carbon-intensive processes.

Internal carbon pricing and reporting

As discussed in chapter 4, large firms tend to apply either proper carbon prices to projects implying some pecuniary transfer or some shadow carbon price to include the environmental dimension in profitability assessments. Both practices are clear expressions of firms' concerns about the impact of ecological transition policies. Such practices can help improve carbon accounting not only at the firm level but possibly also at the product level. For instance, the systematic use of private protocols such as the GHG protocol mentioned previously would improve self-reporting and make it more dependable. Such practice is necessary with regard to several aspects. With an increased sectoral coverage of carbon pricing schemes comes the need to systematically assess firms' emissions. However, governmental, or institutional entities responsible for such assessment may lack the capacity and resources to guarantee exhaustive coverage. Self-reporting may be used to define the CO2 content of most products, assuming that the necessary information is requested in the protocols likely to be imposed. Collecting and centralizing granular information may be challenging, but certainly less challenging than estimating CO2 emissions without precise mandatory information collection protocols. Another positive implication could be the reduction of intra-firm leakage. Even though no precise estimate of this phenomenon exists, given that 40 to 50 per cent of international trade is intra-firm, intra-firm leakage may be significantly high.

6.3 POLITICAL ACCEPTABILITY

Consumers often bear most of the burden imposed by the introduction of carbon pricing schemes. Carbon pricing is therefore generally presented as a crucial tool to effectively change behaviour in order to combat climate change. In practice, policies to affect behaviour may need to include informational features on top of price incentives.

Popular adhesion to climate policy instruments such as carbon taxes is far from guaranteed. In some countries applying such a carbon pricing scheme, about one third of the population is not convinced that climate change is anthropogenic (Dechezleprêtre et al., 2022). Popular support is generally driven by beliefs, which in turn determine attitudes towards the proposed policy instrument. In the context of the yellow vest experience in France in the autumn of 2018, Douenne and Fabre (2020) find that respondents in a massive survey would largely reject a carbon tax even if its proceeds were redistributed uniformly to each adult. These results are shown to be driven by the respondents' overestimation of the tax incidence.

and by the fact that a large majority of individuals erroneously perceived the tax as regressive. Most respondents also expressed serious doubts about the effectiveness of the policy in reducing GHG emissions. Those most opposed to the policy were also the most inclined to overestimate their losses. In a study based on the Swedish carbon tax experience, Ewald et al. (2021) find that opinions on carbon taxes are influenced by educational level, living in a rural versus an urban area, political orientation, and, especially, level of trust in the government. Resistance to carbon taxes does not appear to be influenced by households' income. Similarly to the French case, a lack of conviction about the form of the policy instrument (i.e. a Pigouvian mechanism) is an important motivation for protesters' opposition. On the use of carbon tax revenue, most of the respondents preferred using this to invest in climate mitigation rather than to support uniform revenue refunding. Using an international survey covering five countries,[80] Carattini et al. (2019) show that charges on emissions could be popular if revenues were given back to citizens. In particular, they show that a majority of the people surveyed in all five countries would agree to an $80 carbon tax if the tax revenues were either used to lower income taxes, thus redistributing revenues domestically to each citizen, or earmarked for mitigation projects worldwide. Interestingly, the highest support in all countries was obtained for the reuse of tax revenues in mitigation projects.

Previous evidence clearly shows that price incentives are necessary but potentially insufficient to promote behavioural changes in relation to climate and global warming. If such a risk is not properly accounted for, any political effort to curb emissions may result in counterproductive policies possibly leading to the subsidization rather than the taxation of fossil fuel consumption. Realigning perceptions with the true features of carbon policy schemes is also a necessary condition for policy effectiveness.

6.4 INTERNATIONAL COORDINATION AND COOPERATION

From a global perspective, the cost-effectiveness of carbon pricing is to a large extent affected by the degree of coordination among implementing countries and the extent to which their respective policies are integrated.

As discussed in chapter 3, neither of these two conditions, necessary to obtain carbon price convergence at the international level, are currently met. Most countries have no carbon pricing scheme. As discussed below, large-scale involvement would require proactive international cooperation programmes and systematic transfers whether pecuniary, institutional or technological. As to the risk of leakage, this is anything but comparable across countries or regions. In an ideal situation all GHG-emitting countries would establish some form of carbon pricing scheme. Assuming that the risk of carbon leakage is similar in all economies, a uniform price of carbon could either be defined or could emerge from market forces.

Carbon price uniformization

Complete price convergence across carbon schemes may not be the most desirable outcome. It may be sufficient, at least from an equity point of view, to observe some conditional convergence in line with certain fundamentals that dictate the functioning of carbon pricing schemes or that influence political decisions in different countries or regions. This may lead to optimal differences in carbon prices, if these differences could reflect both economic development gaps and historical emissions paths. Lower carbon prices would then apply in less developed countries. Market forces may not bring out such differentials in clearing prices, however. As suggested by Parry et al. (2021) an internationally agreed scheme for an international carbon price floor (ICPF) may be needed. The arrangement is based on a pragmatic design approach with the explicit objective of accommodating equity considerations and emissions-equivalent alternatives to carbon pricing.

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[80] Australia, India, South Africa, the United Kingdom and the United States.

Climate clubs

Coordination issues may be softened by the creation of a far-reaching international alliance for carbon pricing among a limited number of countries, in the form of climate clubs, as discussed in Nordhaus (2015). Members of such clubs would eventually apply the same price to carbon by harmonizing their carbon pricing schemes. Harmonization could result either in the full integration of ETSs established in the various jurisdictions or in the alignment of carbon tax schemes. Moreover, climate clubs would imply the application of the same carbon border adjustment scheme to non-members. A coordinated and progressive approach to integration, involving first of all the large emitters such as the European Union, the United States of America or China, could help limit the risk of trade conflicts. A building block effect could be observed, in which non-members would be induced to adopt carbon pricing schemes consistent with the schemes prevailing in established climate clubs involving major trade partners. However, the multiplication of climate clubs may also cause some stumbling block effects that may polarize climate action and exacerbate coordination issues.

International transfers

Although developing countries may gain from global mitigation efforts in the long run given their greater exposure to climate risks, in the short run they may have little incentive to undertake costly emissions reductions. Moreover, most developing countries may not be able to raise the necessary funds domestically to promote transition towards cleaner technologies. Institutional capacity to implement carbon pricing schemes such as ETS may also prove limited.

International cooperation is thus crucial to globalize efforts and actions to combat global warming. More advanced countries should make good on their commitments expressed in rounds of COP negotiations to mobilize funds for climate finance for less advanced economies, to help them adopt technologies that transition their economies to lower carbon emissions. Recent IMF estimates[81] indicate that energy-related investments of about $3.3 trillion per year until 2030 will be needed if the objective to achieve net zero carbon emissions by 2050 is maintained.

The Glasgow COP 26 outcome reaffirmed the pledge and urged developed countries to fully deliver on the Paris Agreement $100 billion goal. Developed countries expressed the intention to meet the target in 2023. The Glasgow Pact further called for a doubling of finance to support developing countries in adapting to the impacts of climate change and building resilience. Currently such support represents only about 25 per cent of all climate finance, and 75 per cent of these funds goes towards green technologies to mitigate greenhouse gas emissions. The increase would help to finance policies directed towards the most affected households in developing countries. A strong distributional component would then be constituted and could promote broad adhesion to global climate policy.[82]

Even though the formation of climate clubs may be considered a crucial step towards more systemic international coordination, and eventually more effective climate action, developing countries may be de facto excluded and even discriminated against. This would particularly be the case in the context of the imposition of carbon border adjustment schemes such as the European CBAM, due to be implementing in 2023. The question of possible exceptions to schemes like the CBAM is crucial from a cooperation

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[81] See https://www.imf.org/en/News/Articles/2022/06/01/sp060122-md-opening-remarks-at-the-policy-dialogue-on-climate-and-green-financing#_edn2.

[82] In February 2022, conclusions on the outcomes of the COP26 climate conference were approved by EU foreign affairs minister. The EU and its member States committed to engage with partners around the world to speed up the implementation of the actions and initiatives agreed at COP26. They also called on multilateral development banks and international finance institutions to help mobilize the private sector and shift global financial flows towards sustainable and green investments.

standpoint. However, the granting of exceptions may require a highly granular approach as exports from several developing countries may be governed by strategic production decisions of transnational entities within global value chains. In the latter context exceptions may promote leakage and would thus be counterproductive in terms of global emissions reductions. A partial solution could consist in imposing conditions for obtaining a waiver on carbon border measures. Such conditions could include the establishment of an active ecological transition policy, possibly funded by international financial transfers.

As already discussed, a general solution could rely on the implementation of carbon pricing schemes in most countries. This would automatically weaken the necessity to have recourse to carbon border adjustment schemes to maintain emissions-reduction objectives by avoiding unfair international competition. However, equity concerns may still arise if carbon price uniformization is expected. Because of the possible regressivity of most carbon pricing schemes a lower charge would be justified in some less developed countries to support consumption of poorer individuals. Also in this context, the role of international transfers would be central, as these would help countries consider distributional objectives in their ecological transition strategies.

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ANNEX 1: CO2 EMISSIONS EQUIVALENCES

As discussed extensively in Vallero (2019), different GHGs can have different global warming effects. GHGs differ from each other in terms of energy absorption ("radiative efficiency"), and in terms of permanence in the atmosphere ("lifetime").

The Global Warming Potential (GWP) allows to compare the global warming impacts of different GHGs as reported in the table below. It is a measure of the quantity of energy the emissions of one tonne of a gas will absorb over a given period, relative to the emissions of one tonne of carbon dioxide. The larger the GWP, the more the warming effect as compared to carbon dioxide over that period. The reference period used for GWPs is usually 100 years.

The 20-year GWP can be used as an alternative to the 100-year GWP. It might be more relevant for gases with shorter lifetimes because impacts observed beyond 20 years after the emissions occur are not considered. Because all GWPs are calculated relative to CO2, GWPs based on a shorter time frame will be larger for gases with lifetimes shorter than that of CO2, and smaller for gases with lifetimes longer than CO2.

Global Warming Potentials

		Global warming potential (Time-horizon)		
Gas	Lifetime	*(20 years)*	*(100 years)*	*(500 years)*
Carbon dioxide (CO2)	variable	1	1	1
Methane (CH4)	12±3	56	21	6,5
Nitrous oxide (N2O)	120	280	310	170
Fluorinated gases				
Median	48,3	4600	3800	1400
Max	50000	16300	23900	34900
Min	1,5	460	140	42
Average	3788,281	4564,286	5242,857	6331

Source: IPCC Second Assessment Report available at https://unfccc.int/process/transparency-and-reporting/greenhouse-gas-data/greenhouse-gas-data-unfccc/global-warming-potentials.

Note: The fluorinated gases category covers chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

ANNEX 2: EX ANTE ASSESSMENT OF CARBON PRICING IMPACTS IN DEVELOPING COUNTRIES

Country	Reference	Method/data	Carbon price (US$/tCO2e or %)	GDP variation (%)	Emissions (%)	Carbon revenues allocation	Other effects (% or other)
Brazil	Grottera et al. (2017)	SAM 2002-2003 data (Static)	4.7	-3.1	-5.94	Endogenous budget deficit	Emp.:-3.76
			9.5	-5.4	-10.6		Emp.:-6.68
			4.7	–1.5	-3.92	Endogenous consumption tax	Emp.:-2.38
			9.5	–2.5	-6.8		Emp.:-4.05
			4.7	0.29	-2.96	Endogenous production tax	Emp.:-1.10
			9.5	–2.1	-7.45		Emp.:-3.88
	Pereda et al. (2019)	Input-Output model (Static)	10	-0.2	-1.2	Endogenous budget deficit	Emp: -0.21
			50	-1	-6		Emp: -1.03
			35.68	0.47	-3.4	Reform of domestic tax system	Emp: 0.53
China	Liu and Lu (2015)	CASIPM-GE (2007-2015)	16	-8.15	-1.17	Endogenous budget deficit	Emp.: -0.31 X:+0.27; M:+0.06
				-8.49	-1.1	Endogenous consumption tax	Emp.: -0.33 X:-3-31; M:+0.25
				-7.13	-0.29	Endogenous production tax	Emp.: -0.25 X:+0.42; M:+1.67
	Timilsina et al. (2018)	CGE model (2010- 2030)	0.3 to 3.7	-0.1	-3.3	Endogenous VAT and capital tax	
			1.4 to 22.6	-0.7	-16 (target: -65% w.r.t 2005)		
	Bi et al. (2019)	MCHUGE model (2020-2030)	3.6	-0.13	-0.297		Emp.: -0.038
							X:-0.33; M:-0.22
			ETS	0.02	-0.089	Endogenous budget deficit	Emp.: -0.058 X:-0.42; M:-0.83
			Hybrid	-0.1	-0.364		Emp.: -0.01
							X:-0.73; M:-1.00
	Hu et al. (2021)	CGE model (Static)	0.6	-0.1	-0.84	Endogenous budget deficit	X:-0.32; M:0.1
			1.8	-0.3	-2.6		X:-0.96; M:0.3
			2.25	-0.97	-8		X:-3.09; M:0.98
Colombia	Álvarez-Espinosa et al. (2017)	MEG4C + Microsimulation model (2015-2040)	Sector specific 20<	2020-2040: + 0.15% annually 2020: -0.7 2030: +0.7 2040: +2.3	-20 with respect to emissions projected in 2030	Endogenous budget deficit	
	Calderón et al. (2016)	TIAM-ECN, GCAM, Phoenix, MEG4C models (2020-2050)	50 in 2020 (+4% annually)	–3	-104 (with storage)	Endogenous consumption tax	CO2 neutrality in electricity production

Country	Reference	Method/data	Carbon price (US$/tCO2e or %)	GDP variation (%)	Emissions (%)	Carbon revenues allocation	Other effects (% or other)
Ethiopia	Telaye et al. (2019)	IFPRI model (2018-2030)	From 5 in 2018 to 30 in 2030	-1.6	-1.2	Endogenous sales taxes	Urban emp.: -1.4
				-0.74	-0.52	Transfers to households	Urban emp.: -1
				-1.6	-1.18	Endogenous public savings	Urban emp.: -1.4
				-0.83	-0.73	Endogenous personal income tax	Urban emp.: -1.4
				-1.7	-1.16	Endogenous corporate tax	Urban emp.: -0.9
India	Ojha et al. (2020)	CGE model (2021- 2040)	0.9 to 6.7	– 0.2	-8.8	Transfers to households	Trade bal./GDP -2.87
			0.9 to 6.7	-0.04	-8.6	Transfers to sectors	Trade bal./GDP -2.44
			0.9 to 6.7	–0.04	-8.6	Transfers to households and sectors	Trade bal./GDP -2.65
			0.9 to 6.7	–0.05	-9.8	Transfers to clean energy sectors	Trade bal./GDP -0.62
	Mittal et al. (2018)	AIM/CGE model	Endogenous to meet temp. targett	–3.0 in 2035 –3.2 in 2050	-51 with respect to NDC (2° target)	Endogenous consumption tax	Primary energy demand -29 in 2050
			Endogenous to meet temp. target	–5.8 in 2035 –6.4 in 2050	-64 with respect to NDC (1.5° target)	Endogenous consumption tax	Primary energy demand -38 in 2050
Indonesia	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	0.25	-3.7	Endogenous budget deficit	Rural poverty 21.52
			10	0.27	-3.4	Transfer to consumers (50% revenue)	Rural poverty 21.13
			10	0.26	-3.34	Fiscal reform (50% revenue)	Rural poverty 21.65 (Initial: 21.1)
	Ayu (2018)	GTAP-E model (GTAP-9)	1	0	-1	Endogenous budget deficit	
			7.5	-0.02	-4.2		
			20	-0.07	-9.6		
Iran	Moosavian et al. (2022)	CGE model	10%	-1.38	-24.2	Endogenous budget deficit	Emp: +0.1
			20%	-1.55	-40.3		Emp: +0.2
			30%	-1.91	-51.2		Emp: -0.8
Mexico	Landa et al. (2016)	Three-ME model (2014-2050)	Endogenous to meet emissions target	-3.3 -8	–40 by 2030 –50 by 2050	Endogenous budget deficit + suppression of subsidies	
				0 -2.8	–40 by 2030 –50 by 2050	Endogenous budget deficit + suppression of subsidies + redistribution to consumers and producers	

Country	Reference	Method/data	Carbon price (US$/tCO2e or %)	GDP variation (%)	Emissions (%)	Carbon revenues allocation	Other effects (% or other)
	Octaviano et al. (2016)	MIT EPPA model (2010 to 2050)	10 in 2020 (+4% annually)	-1.5	-35	Endogenous budget deficit	
			50 in 2020 (+4% annually)	-4	-8		
			Endogenous to meet emissions target	-9	–50 compared to 2010 level in 2050		
Philippines	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	-0.04	-3	Endogenous budget deficit	Rural poverty 42.5
			10	-0.03	-2.82	Transfer to consumers (50% revenue)	Rural poverty 40.65
			10	-0.05	-3.35	Fiscal reform (50% revenue)	Rural poverty 41.33 (Initial: 41.4)
South Africa	Alton et al. (2014)	CGE (2010-2025)	3 rising to 30	-1.23	-40.4	Endogenous indirect sales taxes	Employment: -0.56
			3 rising to 30 + CBA	-1.07	-41.4	Endogenous indirect sales taxes	Employment: -0.5
			3 rising to 30 + CBA	-0.59	-41.5	Endogenous corporate tax	Employment: -0.82
			3 rising to 30 + CBA	-1.65	-41.6	Endogenous social transfers	Employment: -1.27
			CBA abroad	-1	-21	Endogenous budget deficit	Employment: -0.83
	Ward and de Battista (2016)	UPGEM model (2015-2035)	8.5	-0.2	-33		Employment: –1.4
Thailand	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	-0.14	-2.38	Endogenous budget deficit	Rural poverty 13.04
			10	-0.08	-2.08	Transfer to consumers (50% revenue)	Rural poverty 12.07
			10	-0.14	-2.49	Fiscal reform (50% revenue)	Rural poverty 14.78 (Initial: 12.6)
	Wattanakuljarus (2019)	CGE model, SAM EPPO 2010 data	1.43	-0.99	-20 by 2030	Endogenous budget deficit	
			1.37	-0.85	-20 by 2030	Endogenous social transfers	
	Puttanapong et al. (2015)	Monte-Carlo CGE model (2010-2019)	6.2	-0.3	-0.7	Endogenous budget deficit	Emp.:–0.7
			12.6	-0.9	-1.5		Emp.:–1.5
			18.9	-1.2	-2.4		Emp.:–2.4

Country	Reference	Method/data	Carbon price (US$/tCO2e or %)	GDP variation (%)	Emissions (%)	Carbon revenues allocation	Other effects (% or other)
United States of America	Woollacott (2018)	ADAGE-US (2020-2040) + COBRA	25 in 2020 (+5% annually)	-1.5	-25.1	Transfers to households	Co-benefits such as reduced mortality
			50 in 2020 (+5% annually)	-2.3	-33.7		
			25 in 2020 (+5% annually)	-0.7	-24.3	Transfers to households and endogenous capital tax	
			50 in 2020 (+5% annually)	-0.1	-32.4		
Türkiye	Kolsuz and Yeldan (2017)	CGE model, 2010 data (2015-2030)	30	-7.2	-31.8	Endogenous green jobs	Emp: -9.5
				1.6	-25.6	Endogenous green jobs+ Endogenous labour tax	Emp: 13
Viet Nam	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	-0.33	-6.29	Endogenous budget deficit	Rural poverty 49.11
			10	-0.22	-5.77	Transfer to consumers (50% revenue)	Rural poverty 45.64
			10	-0.22	-3.67	Fiscal reform (50% revenue)	Rural poverty 49.16 (Initial: 45.0)
	Coxhead et al. (2013)	ORANI-G, AGE models	0.7 on coal, 20 on diesel, 47 on petrol	-0.63	n.a.	Endogenous budget deficit	CPI: 0.72
				-0.46	n.a.	Transfers to households	CPI: 0.59
	Nong et al. (2020)	GTAP-E model	ETS Only energy, transport and agricultural sectors (109)	–4.6	-20 in agriculture -8 in energy and transport	Endogenous budget deficit	Crude oil: 23 Natural Gas: 31.2 Agriculture: -7.5
			ETS All sectors -36	-1.8	-20 in agriculture -8 in energy and transport Baseline in others	Endogenous budget deficit	Crude oil: 8.7 Natural Gas: 13.3 Agriculture: -2.31
	Nong (2018)	GTAP-E model	Tax on petroleum products +33.3% -0.7	–0.5	–10	Endogenous budget deficit	CPI 2.58 Real export –5.58 Real import –3.69
			Tax on petroleum products +33.3% (41 on diesel, 96 on petrol	-2	-7	Endogenous budget deficit	CPI 0.3 Real export –0.57 Real import –0.39

Source: Koh et al. (2021) and author's own elaboration.

Note: In the last column, "X" stands for exports, "Emp" stands for employment, "Urban emp" stands for urban employment and "Trade bal" stands for trade balance.