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Dear reader,

Since 2003, ifo DICE Report has offered a forum for the discussion of institutional questions written by internationally renowned experts. The editorial team's aim was to present findings on current topics in an accessible way. In 2019, we asked readers of all ifo publications how we can make our offer even more useful for their work. Many respondents said their focus was on relevance and topicality, no matter if the topic is presented from a macroeconomic or an institutional economics view. And they would like to have the information presented in a more compact way. Therefore, we decided to put the best elements from two of the English-language publications in our portfolio together: we will merge the ifo DICE Report with the CESifo Forum, the latter providing articles about current economic policymaking from a macroeconomic view.

Starting in July 2020, there will be a "reshuffled" publication under the brand CESifo Forum. It will reflect the scope of activities undertaken by CES and ifo, from scholarly academic research to up-to-date business data and institutional economics. It will be issued bi-monthly and feature articles about the current international economic policy debate. It will start with a "Focus" section, where one current topic is discussed from various angles. It will then feature a "Research Report" and a "Reform Model." Furthermore, it will include a "Statistics Update" of macroeconomic indicators and it will feature a section on "Institutional Comparisons" based on the DICE Database.

We hope you enjoy our new CESifo Forum!

FORUM

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Funding Inclusive Green Transition through Greenhouse Gas Pricing[1]

THE NEED FOR AN INCLUSIVE GREEN TRANSITION

2015 was a special year. During a few months the political stars aligned and made it possible for the international community to agree on the Agenda 2030 for Sustainable Development and the Paris Agreement to limit global warming. Now the signatories need to find ways to implement these agreements, which not only imply a deep decarbonization of the economy but must also meet the Sustainable Development Goals. In this article we discuss the importance of pricing greenhouse gas (GHG) emissions[2] to make this happen. Climate abatement is a truly global public good and so we actually have to have a functioning policy in all countries. Our interest is thus on pricing in all countries but in particular the developing countries that are bigger and most crucial to the struggle for a green transition.

The transition to a sustainable economy will require massive investments in renewables, electricity and transportation networks, buildings, and industry. To wean the world off fossil fuel, massive deployment of renewable energy will be needed. We must rethink our main consumption patterns: Buildings must become largely carbon neutral (energy for heating/cooling drastically reduced and decarbonized). Transport systems must be largely electrified and the electricity come from non-fossil sources. Industry must become carbon neutral – even in really difficult sectors such as steel and cement. Agriculture must transform both with respect to its own production technologies (including methane and nitrous oxide) and, in rich countries, consumption patterns (for example, shifting towards less ruminant meat and dairy products). Deforestation must halt and be reversed worldwide. This list is far from exhaustive, but makes the point that a sustainable climate policy will require *literally thousands of changes in current economic activities.* For economists, the need to simultaneously influence all these activities makes a strong argument for a *price on carbon*. This one policy will incentivize all the changes that can reduce GHG emissions and make carbon-neutral activities more profitable and thus more likely. A carbon tax is a parsimonious policy. Deforestation, for example, would be reduced if the embodied carbon in products like palm oil and beef were properly priced. Decarbonization is crucial but will most likely not be enough: we will also need carbon capture and storage and combined technologies such as bioenergy with carbon capture and storage (Fridahln and Lehtveer 2018) that will be supported by a carbon price.

Engineers and planners prefer to think in terms of providing, in an inclusive, fair, and sustainable way, the necessary technology for transition. This transition includes the weatherization of homes, clean public transport, access to green energy, and many other services. This is a challenge that decision makers in the Global South understand, but they also know it must be funded, in part by public spending. Some of the funding in low-income countries can – and should – come from richer, high carbon-emitting countries. However, a significant part of the funding must also come from within each country. Such funding can in part be obtained by charging for the damage done by emitting greenhouse gases. There are, however, limits to such policies, since people in most developing countries are more concerned about current problems related to poverty than future climate threats.

THE CASE FOR GREENHOUSE GAS PRICING

Economists are convinced of the superiority of carbon pricing: they know it is important to get a consistent, high-price signal to reduce the overall costs of transition, encourage the right choices, and incentivize innovation. Economists know that a price on carbon (through taxes or permit trading schemes) can reduce costs as they equalize the marginal costs of


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[1] This is the first article from the Climate Emissions for Development program of the Environment for Development (EfD) initiative. The writing was initiated at the EfD annual meeting in Bogotá in November 2019. Efficient assistance from Elin Lokrantz as well as referee comments and editorial assistance are gratefully acknowledged. Funding from Mistra Carbon Exit is also acknowledged.

[2] We intend to analyze all greenhouse gases. Carbon dioxide is the most important of these and then comes methane. For simplicity we sometimes speak of carbon, carbon dioxide or CO_2 pricing but in fact we must eventually deal with all the climate gases.

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abatement across different sectors of the economy. It is akin to the message that specialization and trade enhance welfare.

The difficulty is that economic adaptation in response to a carbon tax increase takes time. Popular perception is that higher fuel prices have no effect on consumption: they are "just a tax". This is understandable: the short-run response is quite inelastic. However, the long-term elasticity is sizeable: higher fuel prices do eventually lead to much lower consumption (Sterner 2007). Consumers tend to see only the short-run response. They do not buy the argument that expensive fuels are good for the climate because they force you to economize on fuel. Instead, the only mechanism they see is that money is collected, and they think that the only way a fuel tax will help against climate change is if the revenues collected are spent directly on mitigation.

Carbon pricing makes consumers and firms adopt more efficient technologies and consume goods/services with lower emissions when they choose between investments in fossil or renewable energy. GHG pricing can also promote radically new technologies, but sometimes their fixed costs are so high that even a high carbon price will not change production patterns fast enough. Examples include fossil-free cement or steel, which require major industrial innovations and dedicated industrial policies.

Another argument for carbon pricing is that it may facilitate international treaty negotiation. It has been suggested that it should be simpler and less contentious to agree on one single carbon price rather than mandating emission reductions for each country (Weitzman 2017).

There is a further advantage in choosing carbon taxation for fossil-importing countries. If they *collectively* tax imported fossil fuels, they may attain a triple dividend: (i) they reduce carbon emissions efficiently; (ii) they collect revenue for the state in a way that is less distortive than other forms of taxation; and (iii) they effectively recover some of the rent that oligopolistic fuel exporters would otherwise get. Efficient revenue collection is important. Governments in the Global South have a long list of services that they are expected to provide to their citizens (health, education, infrastructure, security, etc., before considering green investments). But due to a large informal sector and widespread corruption, tax collection is problematic, particularly in rapidly industrializing countries. In such cases, fossil fuel taxes can be more efficient than value added and income taxes, as they lower evasion (World Bank 2015) and cover the informal sector.[3]

ILLUSTRATING SUITABLE LEVELS OF GREENHOUSE GAS PRICE

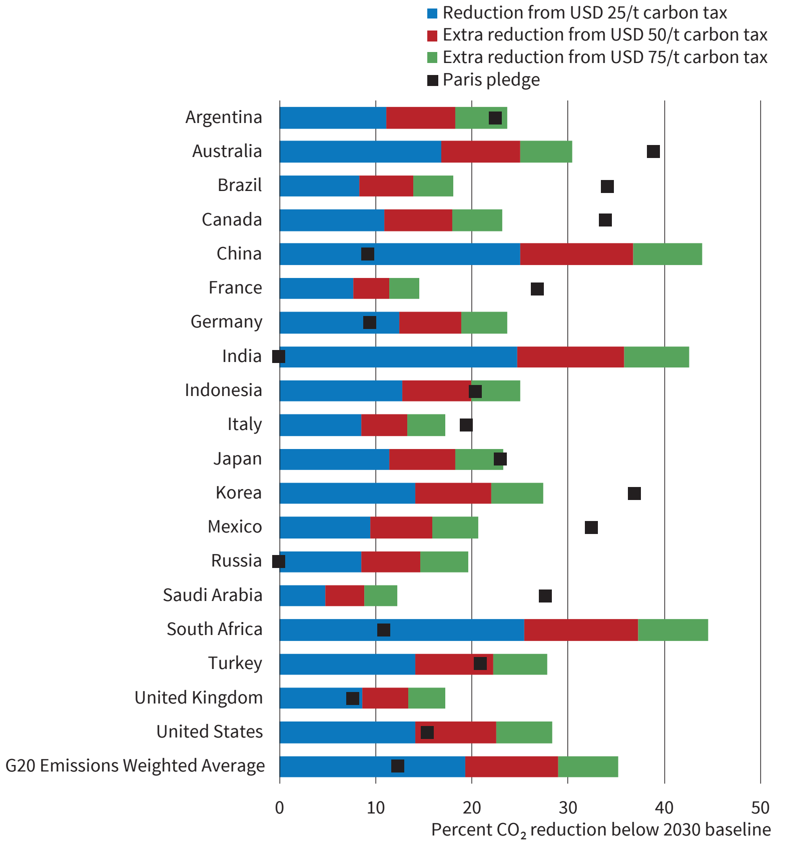
The IMF has developed a spreadsheet tool for projecting fuel use and carbon emissions for the power, transport, household, and industrial sectors. Based on plausible assumptions about the price responsiveness of fuel use by sector, the model can be used to quantify carbon emissions, tax revenues, and economic welfare. The model shows the advantages of carbon pricing compared to other policy instruments. A USD 25 carbon price in 2030 would, by itself, exceed the level needed to meet mitigation commitments in such countries as China and South Africa. In contrast, a carbon price as high as USD 70 would be insufficient in some countries like Australia or Canada, see Figure 1. There are multiple reasons for these differences. One of them is the natural resource base and other features of the economy (does it have fossil or hydro resources, heavy or light industry, etc.) as well as the history of earlier policy making including the level of earlier proactive abatement investments. Finally, the price level needed also reflects the level of ambition in the mitigation commitments.

Suppose there is a USD 50 tax in 2030. Carbon pricing could also mobilize significant revenues, typically around 1–2 percent of GDP. And the pure economic welfare costs (the value of foregone fossil fuel consumption to fuel users) is generally equal to or

[3] For more arguments concerning the role of GHG taxes as a means of resource mobilization, see Besley and Persson (2014) and Franks et al. (2018)

Figure 1

Reduction in Fossil Fuel CO_2 from Carbon Taxes in 2030



Note: Paris pledges indicate the percent reduction in CO_2 emissions below the baseline (that is, no mitigation) levels in 2030 if countries' mitigation pledges submitted for the Paris Agreement are met. Bars indicate the percent reduction in CO_2 emissions below baseline levels under carbon taxes with alternative tax levels.
CO_2 = carbon dioxide; G20 = Group of Twenty.
Source: IMF.

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less than 0.5 percent of GDP (in emissions-intensive countries) – much less than the expected damage costs of climate change. Moreover, the domestic environmental co-benefits (such as reductions in local air pollution, traffic congestion, and accidents) can be large enough that net economic effects are neutral or strongly positive in high-pollution countries like China, India, and Russia (IMF 2019).

THE IMPLEMENTATION CHALLENGE

Although economists have argued for carbon taxes for decades, adoption has been slow. It has been difficult to achieve the necessary public backing to make it politically feasible. People have protested against even small changes in carbon taxes or fuel subsidies. A major source of public concern is that tax proceeds will be ill-spent or appropriated by corrupt politicians. Often *any* price change seems unacceptable, perhaps because of general disapproval of the government. In France, there were big protests when the liter price of gasoline was around USD 1.7, but not in Norway with USD 1.9. Citizens protest price hikes even when prices are extremely low, as in Ecuador (USD 0.50) or Iran (USD 0.12). We will discuss three categories of problem that lead to resistance: carbon leakage, fairness, and lobbies.

CARBON LEAKAGE

Current carbon prices vary considerably from large subsidies in some countries to taxes as high as USD 120/tCO_2 in Sweden. This creates distortions that drive industry concerns over competitiveness and carbon leakage – when companies move production (and emissions) abroad. To date these concerns have been small. Despite current policy heterogeneity, most countries have low taxes or (as in Sweden) have protected some industrial sectors that would be affected. Thus, empirical investigations have not found significant evidence of carbon leakage – but if carbon prices rise significantly, the issue will become more acute. Already today there are many discussions about border tax adjustment and other mechanisms to mitigate the adverse effects of carbon taxes. Certain basic material sectors that are highly emissions-intensive and trade-exposed – e.g., steel, aluminum, cement, and chemicals – are particularly at risk of carbon leakage and this may cause protests concerned about jobs.

REGRESSIVITY, FAIRNESS, AND PERCEPTIONS AFFECTING PUBLIC ACCEPTANCE

Consumer protesters, often motorists (sometimes homeowners with fossil fuel heating) say fuel taxes are unfair. There have been a number of studies concerning the income distribution effects of carbon taxation. While some early US-based studies found regressivity (e.g., Poterba 1991), a more recent, large survey covering transport fuel taxes in over twenty countries found that in a majority of cases, in particular in low income countries, they were progressive (Sterner 2012). In most European countries, they were rather neutral (Sterner 2012). In countries where the existing fuel tax is neutral or regressive, it would furthermore be possible to use the tax revenue collected to create a progressive package. Bureau et al. (2019) considered five different proposals in France ranging from equal repayment per person to schemes that subsidize energy investments in households – or schemes that refund primarily to the poorest deciles of the distribution. They showed that most people in the lower deciles can be made better off, but not all. There are always a few individuals who have very high energy bills (for transport or heating) who are not compensated. Importantly, some protesters fall in the middle of the income distribution and do not necessarily approve of measures of redistribution targeted to the very poorest.

In developing countries, not only fuel but indeed most carbon pricing actually tends to be locally progressive (Dorband et al. 2019). However, poor households can still be adversely affected by carbon pricing. For example, a USD 30 carbon price would cost two billion of the global poor (spending less than USD 3 per day) more than 2 percent of their income. A given tax of USD X will have a bigger impact in a low-income country. This could be used as an argument for somewhat lower tax levels in low income countries, but if the tax difference is large or permanent it will trigger the need for border tax adjustments or tariffs to avoid carbon leakage. Also, for countries where large parts of the population can turn to traditional biomass or charcoal, the pricing of fossil alternatives, such as kerosene, might have unintended side effects on health, the environment, and tax revenues (Olabisi et al. 2019).

Policy acceptability is, however, not tied to income progressivity in any simple manner. There is a good deal of research revealing support varying with policy designs (Drews and van den Bergh 2016). First, attitudes towards new policy measures are based on their perceived distributional effects. The extent to which the consequences of a policy instrument are perceived as *fair* substantially influences the degree of acceptance it receives (Johansson-Stenman and Konow 2010; Kallbekken et al. 2013). However, perceptions of fairness are not always tied to the specific nature of the policy instrument. Often more important is how the revenue generated will be used (Jagers et al. 2019).

Second, acceptance is determined by the extent to which a policy instrument is perceived to impact the individual's freedom of choice, and thus whether it necessitates a change in behavior. Here, the correlations with acceptance are both direct and indirect. Coercive push measures (direct) are generally less supported (Steg and Vlek 1997) and significant infringements of personal freedom of choice (indirect) are also perceived as less fair (Eriksson et al. 2006). Ironically, there may be a contradiction here with optimal taxation literature. The fact that energy taxes are hard to evade in fact makes them "good" taxes in a Ramsey framework – but opponents will often label them as "unfair."

Another strong determinant of support or opposition is the extent to which a policy instrument is expected to achieve its aims, which is often referred to as *effectiveness* (Jagers and Hammar 2009; Kallbekken and Sælen 2011). For more coercive measures, perceived effectiveness is clearly linked to perceived fairness.

Attitudes towards policy measures may also be ideologically constrained (Häkkinen and Akrami 2014; Jagers, Harring, and Matti 2018). Identifying oneself as liberal or left wing typically increases support for environmental policies, including those involving climate change mitigation (Feldman and Hart 2018; McCright and Dunlap 2013; Severson and Coleman 2015), whereas right-wing positioning is connected to skepticism towards government regulation and free-market interventions. Finally, differences in policy support also vary between countries due to differences in political culture (Cherry et al. 2014), wealth and quality of government (Harring 2014), and the political context in which policy decisions are implemented (Linde 2018).

In low-income countries, we face not only opposition from special interests, but also in many cases a lack of interest in future threats simply because the reality of everyday life is already harsh. There are exceptions in, for instance, low-lying coastal areas prone to flooding, but normally the challenges for people on low incomes in Africa or Asia are already so stark that there is little demand for measures to mitigate threats in the somewhat distant future. Hence the democratic mandate for expensive climate policies is limited unless there are significant ancillary benefits such as reduced urban pollution. In these countries, it is particularly important to explain pedagogically the *need* for climate policies.

LOBBIES AS OBSTACLES

Carbon pricing finally faces resistance from the organized interests of polluting industries and extensive lobbying. Clearly, fossil fuel companies lobby against climate policies; the challenge is to understand why they succeed. To some extent, lobbying efforts can be explained by the Stigler-Olson theory of special-interest behavior, which states that successful lobbies arise when special interests are concentrated and well-organized (Inchauste and Victor 2017). In the case of climate change, there are at least two different sets of lobbyists. First, we have lobbyists who represent coal mining, oil, and gas companies. But, second, on the demand side, we also have lobbyists who represent the energy-intensive industries such as fertilizer, aluminum, or transport. In both cases, their concentrated nature gives the preconditions for the formation of strong lobbies. In contrast, the benefits of climate mitigation are very dispersed and occur largely in the future. Despite energy's small share of overall GDP, the share of top 500 companies in energy-related industries is very high. More generally, governments' ability to commit to climate policy is undermined by these strong interest groups, rendering the introduction of carbon pricing difficult (Kalkuhl et al. 2019).

The relative strength of industry opposition to carbon pricing across countries can be explained in large part by several factors: (i) *The share of emissions-intensive (and trade-exposed) industries in a country's economy.* Fossil fuel producing country governments often subsidize fuel, contributing to higher carbon emissions, the crowding out of other sectors and technologies in the economy ("Dutch disease"), and less investment in energy efficiency (Friedrichs and Inderwildi 2013). (ii) *The institutional and procedural structure of the policymaking apparatus.* Important structural properties include the type of government (e.g., democracy/autocracy); the incentive dynamics of party competition (e.g., single-party rule vs. multi-party coalitions); the professional quality of ministries and the civil service; the structure and ownership of energy/emissions-intensive enterprises (state-owned vs. private or joint venture); the interest group system (e.g., pluralist vs. corporatist).

CONCLUSIONS FROM A DEVELOPING COUNTRY PERSPECTIVE

For countries in the Global South, carbon taxes can be politically difficult, but there are multiple reasons why they can be attractive. From an environmental perspective, putting a price on carbon in developing countries is especially important to avoid future lock-in in economies where emissions are still growing fast. One salient example is the ongoing renaissance of coal in India, China, Indonesia, South Africa (Steckel et al. 2015; Edenhofer et al. 2018; Tong et al. 2019), and, more recently, poor countries in sub-Saharan Africa (Steckel et al. 2019). In addition, a carbon price will generally trigger ancillary benefits for other environmental goals such as air pollution. Furthermore, anticipation of stronger climate action including trade barriers from developed countries would mean that it is prudent for all countries to diversify out of risky fossil technologies.

From a fiscal perspective, it is usually difficult to raise taxes in developing economies because the informal sector is a large share of the economy (Besley and Persson 2014). Carbon prices help increase the tax base. A carbon tax could provide revenues for a substantial share of the funds necessary to finance the Agenda 2030 (Franks et al. 2018). Hence, carbon pricing can be an important tool to foster domestic resource mobilization.

Developing countries face challenges regarding the effectiveness of price instruments. The higher capital intensity of low-carbon technologies compared to those using fossil fuels can make moving to these newer technologies more difficult if developing countries face high capital costs. This inability to borrow at world market rates can render carbon pricing ineffective (Hirth and Steckel 2016). It suggests an important role for capital markets.

However, the combination of public skepticism and polluters' lobbying power will make implementation of carbon pricing difficult. For this reason, economists need to think carefully about suitable communication and public-education strategies so citizens better understand why carbon pricing is an appropriate instrument and why it is important to use the revenues collected in a manner that is honest, transparent, and visibly useful for combating climate change. Using revenue from carbon pricing to provide subsidies for weatherizing homes in low-income areas or improving access to affordable public transport is likely to be viewed favorably by the public. Such policies can help meet multiple goals in that they are redistributive in addition to promoting climate goals and reducing local air pollution by lowering emissions.

More fundamentally, for GHG pricing to be seriously considered in many developing countries, its implementation needs to be carefully designed and carried out. In order to predict and enhance acceptability, broad attitudinal surveys can be conducted. In low-income countries, the dire challenges of making ends meet generally imply that development and income opportunities are the prime focus of policy. In many instances, suffering and hardship are commonplace today and thus diverting resources to meet future problems is not necessarily popular. The fact that climate change could actually make lives much more difficult needs to be explained so that policies can be motivated to the general public. The political economy of climate policies needs to be mapped, in particular the identification of carbon lobbies. The effects on carbon emissions, and the distributional implications, of tax incidence and alternative recycling schemes for the tax revenues over time can be analyzed using general equilibrium models. We have argued that carbon taxes are an important part of the policy response, but other measures such as support for new technologies are also needed. We must collaborate with researchers in all countries to make sure everyone has the capacity to carry out appropriate analyses and design policies.

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China had relied mostly on administrative means to meet its 20 percent energy-intensity reduction goal for 2010 (Zhang 2010a,b and 2011a,b). These administrative measures were effective but not efficient. In the end, China had limited success in meeting its goal (Zhang 2011a,b). Going forward, China has realized that it cannot continue to rely on costly administrative measures to honor its pledge to cut its carbon intensity by 40–45 percent by 2020 relative to its 2005 levels and its commitment to cap its carbon emissions around 2030 and to try to peak early. These commitments were officially incorporated into China's Intended Nationally Determined Contributions submitted to the UNFCCC (United Nations Framework Convention on Climate Change) Secretariat. In addition, China pledged to reduce the carbon intensity of its economy by 60–65 percent by 2030 compared to 2005 levels (NDRC 2015).[2]

As an integrated package of mitigating carbon emissions and combating global climate change, the National Development and Reform Commission (NDRC) in late October 2011 approved seven pilot carbon emissions trading schemes in Beijing, Chongqing, Guangdong, Hubei, Shanghai, Tianjin, and Shenzhen. The seven pilots are deliberately selected to be located in regions at varying stages of development and are given considerable leeway to design their own schemes. These schemes have features in common, but vary considerably in their approach to a variety of issues, such as the coverage of sectors, allocation of allowances, price uncertainty, and enforcement and compliance. All launched their first trading from June 2013 to June 2014. In December 2017, NDRC (2017) announced the launch of a national emissions trading scheme (ETS) to regulate the CO_2 emissions from the power sector and released a work plan for construction of the national carbon emissions trading market (power generation sector).

This article examines China's carbon trading pilots, the design, implementation, and compliance of the national ETS, and the pressing work to ensure that the national ETS functions properly and achieves a smooth interconnection of the carbon trading pilots and the national ETS.

CARBON TRADING PILOTS

All pilot schemes have some features in common. All of the pilots cover CO_2 only except for the Chongqing pilot, which considers all six greenhouse gases covered under the Kyoto Protocol. Moreover, all pilots require third-party verification of the emission reports of the entities covered.

In the meantime, the seven pilot regions are given considerable leeway to design their own schemes. The pilot schemes have different coverage of sectors, ranging from 6 sectors in Guangdong to 26 sectors in Shenzhen. The threshold to determine whether an emissions source is covered differs across pilots. A combination of the two factors leads the number of covered entities to differ significantly, from 107 in Tianjin to 947 in Beijing. Consequently, the share of covered emissions in the total emissions in each pilot region varies significantly.

Differing from the ETS of the European Union and California, the covered emissions sources are enterprises in all the pilot schemes in China. Also, unlike the EU ETS, all the pilot schemes cover indirect emissions both from electricity generated within the pilot region and from electricity imported from outside pilot regions. This design feature could help to reduce carbon leakage (Zhang 2015a).

In each pilot scheme, the majority of allowances are for initial distribution, with a small portion of allowances used for adjustments, for new entrants, and for auctioning, and reserved for maintaining the price stabilization. While the allowances are granted to new entrants based on benchmarking, allocations to existing emissions sources are based on historical emissions, emissions intensities, or benchmarking depending on sectors. Even if allowances are grandfathered on a historical basis, the treatment of early abatement actions differs among pilots in terms of time profile of historical emissions, allocation methods, and allowance reward. In most pilots, allowances are allocated for free year by year, whereas the Beijing and Shanghai pilots distribute all the 2013–2015 emission allowances for free for all the covered enterprises at one time. Beijing and Shanghai shifted to an annual cycle in 2016 to allow intertemporal flexibility to update the cap. The pilots also allow the mandated entities to apply for adjustments in allowances in case a significant shortage of allowances occurs, but the conditions and mechanisms for ex post adjustments in allowances differ across pilots.

All carbon trading pilots in China except for Chongqing have reserved a small portion of allowances for cost containment purposes, but only Beijing sets a specific ceiling and floor price at which the regulator can, but is not required to, release

[1] This article is based on the two lengthy articles by Zhang (2015a,b), which provide full references to all the data cited. This work is financially supported by the National Natural Science Foundation of China under grant Nos. 71690243 and 71373055.
[2] See Zhang (2017) for further discussion on stringency of China's climate commitment.

allowances from the reserve or buy back allowances. To limit price volatility, all pilots design daily trading risk management mechanisms to regulate the maximum increase and decrease of daily prices (typically around 10 percent to 30 percent). All pilots allow banking, but it is only in the Hubei pilot that allowances that have been transacted can be banked to enhance liquidity. Borrowing is not authorized. All pilots allow to varying degrees the use of China Certified Emission Reductions (CCERs), ranging from 5 percent to 10 percent of their emissions caps, but pilots differ regarding the origin of CCERs.

Ways to prevent market power of dominated players, or at least mitigate market power concerns differ. Some pilot regions set limits to the amount of allowances that each entity can bid, while other pilots specify the ways to handle larger orders of allowances. To enforce the compliance of covered entities with their emissions obligations, all pilots have built a variety of public disclosure and punishment mechanisms. Some pilots deprive those non-complying entities for a certain period of time from applying for public energy saving funds, and from being given preferential treatment in their application for public financial support for low-carbon development, energy conservation, and renewable energy projects. Some pilots go further. In the Beijing pilot, depending on the extent of noncompliance, entities are subject to fines equal to three to five times the prevailing average market prices over the past six months for each shortfall allowance. Non-complying entities in the Hubei pilot are charged at 1–3 times the yearly average market prices for each shortfall allowance, with the imposed penalty capped at CNY 150,000, and two times the amount of their shortfall allowances are deducted from the amount to be allocated in the following year. The Shenzhen and Shanghai pilots auction additional allowances, with eligibility specified only for those enterprises of compliance gap, and the allowances received are only for compliance needs and cannot be traded on the market.

By June 2014, all seven carbon trading pilots had begun trading. These pilots together cover about 2,900 entities in 2019, with the total amount of allowances capped at 1.16 billion tons of CO_2 emissions (Zhou 2020). According to the Vice Minister of China's Ministry of Ecology and Environment (MOEE), by the end of October 2019, the total accumulated value of traded allowances by all carbon trading pilots reached CNY 7.68 billion, and the total accumulated volume of traded allowances reached 347 million tons of CO_2 (Zhang et al. 2019). But pilots differ significantly in the total accumulated volume and value of traded allowances and the resulting average price, with the total accumulated volume of traded allowances ranging from 44.7 million tons of CO_2 in Guangdong to 51,160 tons of CO_2 in Chongqing, and the yearly average price per ton of traded allowance ranging from CNY 83.3 in Beijing to CNY 6.9 in Chongqing in 2019 (Hong 2020). In terms of compliance, Shanghai is the only pilot that has consecutively achieved a compliance rate of 100 percent since launching trading in 2013. Guangdong and Hubei have achieved a compliance rate of 100 percent four times consecutively. Moreover, all pilot regions have not only cut their total carbon emissions; the carbon intensity of the covered entities goes down year by year. For example, through technical innovations, 80 percent of the covered enterprises in Guangdong were estimated to have cut to differing degrees their emissions per unit of product (Li and He 2014). This is a significant accomplishment for a big manufacturing province like Guangdong.

TOWARD A NATIONWIDE ETS

In December 2017, NDRC released a work plan for construction of the national carbon emissions trading market (power generation sector). This sectoral coverage is much narrower than the initially planned coverage of eight sectors (power generation, metallurgy, nonferrous metals, building materials, petrochemicals, chemicals, papermaking, and aviation). The threshold for an emissions source from the power generation sector to be covered is set at 26,000 tons of CO_2 equivalent per year. As such, 1,700 power generation firms are estimated to be covered in the national ETS (For reference, the 10,000 Enterprises Energy Conservation Low Carbon Action Program covers 16,078 enterprises. They include industrial and transportation enterprises consuming energy of 10,000 tons of coal equivalent (tce) and other entities consuming energy of 5,000 tce in 2010.). Combined, they emit over 3.3 billion tons of CO_2 annually, which is about 30 percent of China's overall CO_2 emissions (ICAP 2018). Once put into operation, this would establish China's ETS as the world's largest scheme.

Based on the MOEE's interim measures for carbon emissions trading, the national ETS will be governed by the two-tier management system (MOEE 2019a). MOEE is mandated to set national rules to ensure, among other things, the same rules regarding coverage and scope; uniform standards for monitoring, reporting and verification, and the allocation of allowances; and standard rules of compliance across provinces or equivalent. In the meantime, local ecology and environment bureaus (LEEBs) are assigned to take responsibility for implementing the rules. This includes but is not limited to identifying the entities covered and determining their emissions, calculating the amount of free allowances to the entities covered and, once approved by the local government and submitted to the MOEE, distributing these allowances to the entities and implementing compliance rules. LEEBs should be allowed to set even stricter rules than the national rules. For example, they could increase the coverage of sectors and the scope of entities, and have even stricter rules for the allocation of allowances.

The initial distribution of allowances will be free, with allowance reserves for adjustments, for new entrants, and for auctioning, and reserved for maintaining the price stabilization. Benchmarks will be used for initial allocations wherever possible. In September 2019, the details of the benchmarks for thermal power generation units were released (MOEE 2019b). Without giving preference, two options are given for the trial calculation of allowances. One option classifies the units into three categories (conventional coal fired, unconventional coal fired, and gas turbine). Another option classifies the generation units into four categories by further dividing the conventional coal-fired units into two types based on scale (over 300 MW, and 300 MW and below) (MOEE 2019b). Differing from the pilot schemes where offsetting is allowed to different degrees, CCERs are not allowed in the national ETS until the market becomes mature (NDRC 2017).

To make the carbon market run smoothly, the national ETS will establish the regulatory framework for mitigating carbon trading risk management. Mechanisms to manage excessive price volatility include daily price limits that regulate the maximum increase and decrease of daily prices, risk-warning, and auctioning additional allowances to those entities of compliance gap (MOEE 2019a). However, the extent to which the daily trading risk management mechanisms are activated is unspecified.

To enforce the compliance of covered entities with their emissions obligations in the national ETS, penalties are imposed both on auditors and on entities that do not comply with reporting requirements. To increase the rate of compliance, noncompliance is included in the credit record of non-complying entities and is made public to financial institutions and the general public. Given that the penalty for non-complying entities in the Shanghai pilot is not the strictest as compared to its peers, this provision is considered as key to helping Shanghai achieve 100 percent compliance. Moreover, non-complying entities are charged at 2–5 times the yearly average market prices for each shortfall allowance (MOEE 2019a). In the Beijing pilot, a fine of three times the average market price is imposed if the emissions of non-complying entities exceed their emissions allowance by less than 10 percent, while a fine of five times the average market price is applied if non-complying entities emit 20 percent more than their emissions allowance. If the non-complying entity's emissions are more than 10 percent but less than 20 percent of the allowance, a fine of four times the average market price is imposed (BMDRC 2014). However, the extent of noncompliance and the corresponding fine have not yet been disclosed in the national ETS.

FURTHER WORK FOR THE NATIONAL ETS TO FUNCTION PROPERLY

The carbon trading pilots started trading in June 2013. These pilots have experienced ups and downs, but they generally perform in line with expectation. Their strong start and performance not only suggest that emissions trading is a useful means of helping the covered entities to meet their emissions obligations; they also encourage development of China's national ETS. Building on these carbon trading pilots and a lot of preparation work, the national ETS was planned to launch in 2019, but has been delayed to 2020/2021. More work needs to be done to ensure that the national ETS functions properly and that a smooth interconnection of the carbon pilots and the national ETS is achieved.

Ideally, national ETS legislation needs to be established to authorize emission trading at the national level. The aforementioned MOEE's interim measures are not enough. The provisions governing emissions trading across regions in the form of interim measures need to be elevated to a level of greater legal strength, at least to the State Council's regulation. This is essential because disputes could become more intensive and frequent as the carbon market expands beyond the institutional jurisdiction of administrative regions.

The initial coverage of power generation and the high threshold under the national ETS imply coexistence of regional and national ETSs. Until a nationwide carbon market becomes fully functional, the regional ETS will continue to function in parallel and those entities covered in the existing regional ETSs will be unconditionally integrated into a nationwide ETS if they meet the latter's threshold. This raises the issue of achieving a smooth interconnection of the carbon pilots and the national ETS. A variety of the pressing issues that need to be addressed include how to integrate carbon pilots into a united, nationwide carbon market; how to deal with a potential surplus of unused allowances under carbon pilots as the pilot phase ends; how to deal with those sectors covered in the pilots but not in the national ETS; how to strike a balance between pilots' preferences to keep their own autonomy and characteristics and the need to have a harmonized national carbon trading scheme; how to ensure that each unit of emissions reduction is reliable and comparable among sectors and across regions; and how to deal with the potential of intensive and frequent disputes as the carbon market expands beyond the jurisdiction of administrative regions, just to mention a few.

Let us focus on one thorny issue, that is, unused allowances from the seven pilot markets. Ruling out the banking of these allowances to the national scheme would likely cause regional carbon prices to crash. But allowing all or some of the units to be carried forward, while maintaining their value, would risk burdening the national market with a sizeable oversupply upon its launch. There are several options. One is to consider a conversion mechanism that would allow pilot allowances to be eligible in the national market, but at a discounted value. A conversion rate would depend on the degree of over-allocation and the price levels in the market from where they originate, giving surplus allowances from very over-allocated pilots a higher discount rate than those from the markets with only slight surpluses. Another is to allow the pilot permits to be used, but only for a portion of the allowances carried forward each year in a limited period. The third option is to link the level of allowances with bankable surplus allowances from the pilot region. This will let allowances from the pilot carbon markets be banked to the national emissions trading system, but at the expense of reduced allocation levels in that region. Which option would prevail in the end will depend on the outcome of intense negotiations between the central government, regional governments, and industry over how to treat unused allowances from the seven pilot markets in the national ETS, and could have a huge bearing on the success of the world's biggest carbon market. Furthermore, price uncertainty and market stabilization are expected to become even bigger issues in a nationwide ETS. Using reserved allowances for cost-containment purposes in carbon pilots may be even more problematic in a national ETS. Thus, an easy but effective measure against price uncertainty would be to introduce both a price ceiling and a price floor.

The MOEE's interim measure indicates that those equivalent to allowances can be used to meet the emissions obligations of the covered entities (MOEE 2019a). This is widely considered as a green light for the use of the offsetting, but the types and conditions to use offsetting have not been specified. To help lower the compliance costs of the covered entities in the national ETS and encourage those not covered in the national ETS to take more abatement actions, combined with the lessons learned from the pilots in this context, there is great necessity to authorize the use of a flexible offsetting mechanism and specify the mechanism's conditions of use.

Experience in the pilot regions shows that the entities have not recognized that emissions trading is not only a means of helping the covered entities to meet their emissions obligations, but it can also help them achieve that goal at low costs. Many entities believe that governments may not be that serious about enforcing compliance, so they take advantage of emissions trading only at the last minute. While the majority of them meet their obligations in the end, they pay higher prices than what would otherwise be the case. For example, the total volume of traded allowances in the last month in Beijing, Shanghai, and Shenzhen accounted for 75 percent, 73 percent, and 65 percent, respectively, of the total accumulated volume of trade from the first to the last trading day of the first-year compliance circle. Consequently, not only the volume of traded allowances rose rapidly in the last month of the compliance circle; so did their online trading prices (Zhang 2015b). Chongqing, as a representative region of China's development level, performed poorly in the overall compliance of the seven pilots. All these suggest that the expansion of carbon trading pilots to a nationwide ETS is not easy, and that educating the covered entities and strictly enforcing compliance rules are crucial to enabling active participation in carbon emissions trading.

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Carbon Pricing in a Federal State: The Case of Canada

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As of January 2020, Canada has broad-based emissions pricing in place across the country. The most interesting part of this implementation is the lack of uniformity, both in terms of policy design and policy implementation. The policy design differences include: one province with a broad-based carbon tax; two provinces with a cap and trade system; the remaining provinces and territories have a hybrid carbon tax plus large-emitters' output-based subsidy system; and numerous province-specific exemptions. The implementation differences are: six provinces and one territory designed and adopted their policies voluntarily; two territories adopted the federal policy voluntarily; one province had part voluntary adoption and part federally imposed policy; and three provinces had the federal policy fully imposed.

The differences in policy design and implementation stem from Canada's institutions and recent political changes. The *Constitution Act,* 1867 articulates the powers held by the federal government and provincial and territorial governments, and where there is shared jurisdiction. Residual power resides with the federal government (Brouillet 2017). While Canada typically operates under principles of cooperative federalism (Glover 2016), regional tensions frequently arise. Common sources of tension are federal-provincial/territorial disputes over areas of shared jurisdiction, over the relative importance (economic and political) of each order of government in Confederation, and over fiscal federalism.

The Constitution is silent on the environment, making it nominally federal but in practice an area of shared jurisdiction, in part due to clarifying Supreme Court of Canada decisions (Government of Canada n.d.-k). As a result, environmental policies are often contentious and political. Carbon pricing, while not initially a source of discord, has become so recently. Despite signing the Kyoto Protocol in 1997, the federal approach to emissions was sector-by-sector regulation (Hoberg 2016). Leadership came from provincial action, until a federal political change in 2015. Provincial leadership created the space for the federal government to push concerted pan-Canadian emissions pricing, with federal policy as a backstop.

While political change at the federal level enabled concerted and coordinated emissions pricing, subsequent political change in several provinces weakened the coalition of the willing and undermined the feasibility of pan-Canadian carbon pricing. The remainder of this paper outlines the evolution of emissions pricing and the political changes that led to implementation and political retreat from emission pricing, then comments on the lessons from the Canadian experience.

THE EVOLUTION OF EMISSIONS PRICING IN CANADA

Canada signed the Kyoto Protocol in 1997, committing to a 6 percent reduction in emissions by 2012, relative to a 1990 baseline (Canada 2007). Despite this commitment, and signing the Copenhagen Accord in 2009, federal policy was slow-moving and focused on sector-by sector regulation (Hoberg 2016).[1] Table 1 outlines milestones in Canadian emissions pricing policy. Policy leadership on this file came from provinces: in 2007, Alberta was the first jurisdiction—in Canada and North America—to implement emissions pricing when it introduced a performance-based standard with a compliance charge for facilities with annual emissions greater than 100,000 metric tons of CO_2-equivalent (CO_2e). While a significant and important move, Alberta's climate policy goals still fell short of Kyoto Protocol commitments (Government of Alberta 2008). British Columbia followed in 2008 with a broad-based carbon tax on combustion emissions, which enjoyed broad support, in part due to its low initial tax rate (CAD 10 per metric ton of CO_2e) and revenue-neutrality.

In conjunction with several US states, provinces created the Western Climate Initiative (WCI) to support development of emissions trading programs (Western Climate Initiative 2007). This international cooperative approach allowed for policy transfer and led to some policy convergence (Boyd 2017). Membership in the WCI led Quebec to implement its cap and trade program in 2013, and link with California in 2014.

The year 2015 had two significant political[2] events that changed the calculus of environmental policy in Canada. First, the election of the center-left New Democratic Party (NDP) in Alberta in May 2015 ended almost 45 years of center-right governance. Almost immediately after forming a government, the NDP announced an expert panel tasked with developing a new climate change strategy for Alberta (Government of Alberta n.d.-d). In November 2015, the panel released its report and the government announced its ambitious Climate Leadership Plan, which would implement a carbon tax on households and small emitters, cap oil sands emissions, phase out coal-fired electricity generation, and migrate the large-emitter system to output-based pricing. The Climate Leadership Plan was a major policy shift in Alberta, the largest source of emissions in Canada (38 percent in

[1] Provincial policy also generally focused on regulation and targeted subsidy programs, rather than broad-based policy.
[2] Canada has a Westminster-style parliamentary democracy.

2015) and the largest source of industrial emissions (Environment and Climate Change Canada 2019). With Alberta's Climate Leadership Plan, three major provinces—in terms of economic size (74 percent of Canada's GDP in 2015 [Statistics Canada n.d.]) and emissions (71 percent in 2015 [Environment and Climate Change Canada 2019])—had broad-based emissions pricing in place or planned.

Second, the fall 2015 federal election changed the government from the center-right Conservative Party to the center-left Liberal Party. The Liberals' campaign platform included a commitment to carbon pricing (Liberal Party of Canada 2015).[3] At the Conference of the Parties (COP) 21 in Paris, Prime Minister Justin Trudeau stated, "Canada is back" (Trudeau 2015), implying that climate policy in Canada would no longer lag behind other countries. Canada signed the Paris Agreement, and ratified it in 2016, setting in place new targets (Canada n.d.-q).

The presence of emissions pricing in three provinces, plus the federal commitment to leadership on the file, created the conditions for broad agreement on a way forward. In March 2016, the first ministers released a joint communique, called the Vancouver Declaration on Clean Growth and Climate Change, which recognized provincial and territorial leadership and committed to "meeting or exceeding Canada's 2030 target" (Canadian Intergovernmental Conference Secretariat 2016). The next major policy milestone was the joint release of the Pan-Canadian Framework on Clean Growth and Climate Change (PCF) in December 2016, which included a commitment to implement pan-Canadian emissions pricing (Environment and Climate Change Canada 2016, 2017). The PCF introduced minimum requirements for emissions pricing and coverage (proportion of emissions priced) and committed to flexibility in policy development at the provincial level, with a federal policy "backstop".[4] Notably, the three provinces with pricing in place—Alberta, British Columbia, and Quebec—were examples of implementation options.

In 2017, Ontario joined the ranks of provinces with emissions pricing; at this point, all "major" provinces—by economic size and emissions—had pricing in place. However, as federal technical material on implementation of the PCF began to roll out and provincial governments began to develop their pricing policies, cracks developed in this fragile coalition. Combined with political changes in 2018 and 2019, consensus over what pan-Canadian emissions pricing would look like fell apart. Notably, elections in Ontario and New Brunswick led to changes of government, and reneging on commitments to carbon pricing. Ontario canceled its cap and trade system in July 2018, and by fall 2018, only six provinces were deemed compliant with the federal benchmark. Four provinces had the federal backstop imposed in whole or in part. The remainder would adopt the federal backstop voluntarily. In May 2019, Alberta's NDP government lost power, and the new Alberta Conservative Party government repealed the carbon tax in its first bill. Alberta switched from being a voluntary participant—and leader in developing carbon pricing in Canada—to a jurisdiction with federal pricing imposed.

In a watershed moment for Canadian climate policy, it became a first-order policy issue in the 2019 federal election, pitting Liberal commitment to the PCF against federal Conservative policy supporting regulation over market-based policies. The Liberals were re-elected with a minority, cementing carbon-pricing policy for the near term, and perhaps indefinitely. The success of the Liberals led to recalcitrant province New Brunswick ending its opposition to the PCF, and developing a new pricing policy, accepted in late 2019 by Canada (Poitras 2019).

The next test of carbon pricing came as three provinces—Alberta, Saskatchewan, and Ontario—filed reference cases with their respective Courts of Appeal on the constitutionality of the Greenhouse Gas Pollution Pricing Act, the federal act implementing the PCF. The Ontario and Saskatchewan courts ruled in favor of the federal government (though both cases had split decisions), and Alberta's court ruled against the federal government; Ontario and Saskatchewan have since referred the case to the Supreme Court of Canada. The outcome of this case will likely determine the future of coordinated emissions pricing in Canada.

LESSONS FROM A FEDERAL STATE

As discussed above, provincial action in Alberta, British Columbia, and Quebec (and later, Ontario) created space and opportunity for federal action. It also shows that federal policy is not necessary for action, though the result can be less consistency in policy formulation. Moreover, it is no accident that when Canada announced the minimum standard in emissions pricing, the systems in these three provinces (carbon tax in British Columbia, cap and trade in Quebec, and hybrid carbon-tax and output-based pricing in Alberta) were explicitly identified as options for implementation. Alberta was also a lynchpin in this policy system—as Canada's largest subnational emitter, its progressive policies on emissions created a clear example for other provinces. Alberta's output-based pricing system (the *Carbon Competitiveness Incentive Regulation*) formed the building blocks for the federal output-based pricing system.

A key commitment of the federal government was allowing for flexibility in policy design among provinces, recognizing each had unique situations and unique challenges. These differences lead to clear efficiency losses when viewed with the lens of economic theory. However, policy to mitigate climate

[3] In 2008, the Liberal Party also campaigned on carbon pricing, but were unsuccessful in forming a government, and was relegated to third-party status from Official Opposition.
[4] The PCF was a joint release of the federal government, and all provinces and territories except for the province of Saskatchewan.

Table 1

Summary and Timeline of Emissions Pricing Policies in Canada

Year	Policy	Policy Design and Coverage
2007	Province of Alberta adopts *Specified Gas Emitters Regulation* (SGER).	Performance standard on facility-specific historical emissions per unit of production, requiring 12 percent improvement in emissions intensity by ninth year of operations. Compliance via reducing emissions, purchasing offset credits, or paying CAD 15 per metric ton to the Climate Change and Emissions Management Fund. Combustion and process emissions (24 specified gases) from facilities emitting more than 100,000 metric tons of CO_2-equivalent annually.
2008	British Columbia implements carbon tax.	Revenue-neutral, with rebates to lower-income households and reductions in other taxes. Initially CAD 10 per metric ton CO_2e, rising by CAD 5 per metric ton per year until it reached CAD 30 per metric ton in 2012. Combustion emissions from fossil fuels.
2013	Quebec implements cap and trade system.	Declining annual emissions cap, with increasing floor price for emissions permits. Free allocation of permits to emissions-intensive and trade-exposed (EITE) designated industries. Covered facilities are industrial facilities and electricity producers and importers with annual emissions greater than 25,000 metric tons of CO_2e.
2014	Quebec links cap and trade system with California.	Quebec system augmented with joint permit auctions with pre-determined auction exchange rate. Price floor is the higher of the two jurisdictions' price floor after currency conversion.
2015	Alberta increases stringency of *Specified Gas Emitters Regulation*.	Emissions intensity limit changes from 12 percent improvement by ninth year of operations relative to facility baseline to a 15 percent improvement in 2016 and a 20 percent improvement in 2017. Charge for offset credits increases to CAD 20 per metric ton in 2016 and CAD 30 per metric ton in 2017.
	Alberta announces Climate Leadership Plan.	Emissions pricing, phase out coal-fired electricity generation by 2030, generate 30 percent of electricity from renewables by 2030, cap oil sands emissions at 100,000 metric tons of CO_2e per year, and reduce methane emissions from upstream oil and gas by 45 percent by 2025, relative to 2014.
2016	Quebec adds fuel distributors to cap and trade system.	Coverage expands to include fuel distributors whose annual emissions are lower than 25,000 metric tons of CO_2e and who distribute 200 liters of fuel or more.
	Pan-Canadian Framework announced, endorsed by federal government and all provinces and territories except Manitoba and Saskatchewan.	Commitment to implement Canada-wide emissions pricing, with complementary mitigation and adaptation measures. Flexibility for provinces and territories to design their own policies. Carbon pricing to be in place by 2018. Introduces federal benchmark (minimum price and coverage), which provincial plans will have to meet. Canada will develop a "federal backstop," an emissions pricing policy that will apply in jurisdictions with pricing plans deemed insufficient. Minimum coverage of substantively the same as British Columbia's carbon tax. Provinces can opt for a BC-style carbon tax, an Alberta-style hybrid with carbon tax plus large-emitter output-based pricing system, or a Quebec-style cap and trade system.
2017	Ontario implements cap and trade system.	Declining annual cap and increasing annual minimum price. Free allocation of permits to facilities with specific criteria; declining annual cap of free allocations. Auction revenue directed to lower-income northern households and to supplementary projects/programs to reduce GHGs. Covered facilities include electricity importers, facilities, or natural gas distributors with annual emissions greater than 25,000 metric tons of greenhouse gas emissions, and fuel suppliers that sell more than 200 liters of fuel per year. Voluntary participation for facilities with annual emissions between 10,000 and 25,000 metric tons.
	Alberta passes *Climate Leadership Act* (January).	Levy applied to combustion emissions from fossil fuels, by households and small industrial emitters not regulated under SGER. Levy starts at CAD 20 per metric ton in 2017 and rises to CAD 30 per metric ton in 2018. Revenue used to provide means-tested rebate for lower-income households, reduce small business corporate tax rate, subsidize renewable energy deployment, fund "green infrastructure", fund energy efficiency programs, and transition payments to coal-generation facilities. Exemptions for fossil fuel used in oil and gas production process, farm fuel, and fuel used as a non-energy input in a manufacturing process.

	BC increases carbon tax rate (September).	Increased to CAD 30 per metric ton effective April 1, 2018, and will increase by CAD 5 per metric ton until it reaches CAD 50 per metric ton in 2021. Increased rebates to lower-income households and eliminates revenue neutrality requirement. Coverage remains the same.
	Alberta replaces *Specified Gas Emitters Regulation with Carbon Competitiveness Incentive Regulation* (CCIR).	Charge on facility emissions above product-specific benchmark, with sector-specific output-based allocations of emissions credits. Increasing benchmark stringency and declining output-based allocation rate. Compliance via reducing emissions, purchasing offset credits, or paying CAD 30 per metric ton to the Climate Change and Emissions Management Fund. Combustion and process emissions (24 specified gases) from facilities emitting more than 100,000 metric tons of CO_2-equivalent annually. Opt-in provisions for (1) facilities competing against CCIR-regulated facilities, or (2) facilities with annual emissions greater than 50,000 metric tons of CO_2-equivalent and designated as emissions-intensive and trade-exposed.
	Ontario links cap and trade system with Quebec and California (January).	Ontario system augmented with joint permit auctions with pre-determined auction exchange rate. Price floor is the highest of the three jurisdictions' price floors after currency conversion.
	Ontario cancels cap and trade system (July).	Removes all emissions pricing. Compensation available for participants. Cancels programs funded via cap and trade revenue.
2018	Canada passes *Greenhouse Gas Pollution Pricing Act* (GHGPPA).	Implements a fuel charge on 21 types of fuel and combustible waste, and an output-based pricing system for large industrial emitters. Listed provinces (where provincial pricing systems are deemed insufficient in whole or in part) are subject to the *GHGPPA*. Fuel charge exemptions for agriculture, fishing, greenhouses, and power plant operators for remote communities. Revenues from fuel charge used for household rebates, supplementary rebate for households in remote communities, and support for specific sectors. Output-based pricing system applies to facilities with annual emissions of 50,000 metric tons of CO_2e or more in 2014 or later. Opt-in provision for facilities with emissions greater than 10,000 metric tons annually and (1) are in an industry with a federal output-based standard, or (2) are designated as emissions-intensive and trade-exposed.
	Canada announces how emissions pricing will occur across Canada (November).	Provincial/territorial systems approved and apply in Alberta, British Columbia, Quebec, Nova Scotia, Prince Edward Island, Newfoundland and Labrador, and Northwest Territories. Federal fuel charge applies in Saskatchewan, Ontario, Manitoba, and New Brunswick, effective April 1, 2019. Federal output-based pricing system applies in Ontario, Manitoba, New Brunswick, and partially in Saskatchewan, effective January 1, 2019. Federal output-based pricing system voluntarily adopted by Prince Edward Island. Territories of Nunavut and Yukon voluntarily adopt federal backstop (full *GHGPPA*).
	Quebec introduces voluntary registration in cap and trade system.	Expands to include industrial facilities with annual emissions greater than 10,000 metric tons of CO_2e and less than 25,000 CO_2e.
2019	Alberta repeals carbon levy (June).	Removes emissions pricing from fossil fuel combustion and facilities not regulated under CCIR.
	Canada announces Alberta will become a listed province (June).	Canada implements federal fuel charge in Alberta effective January 1, 2020.
	Canada approves New Brunswick carbon tax plan (December).	New Brunswick plan uses revenues for adaptation and mitigation.
2020	Alberta replaces CCIR with *Technology Innovation and Emissions Reduction (TIER) Regulation*.	Combustion and process emissions from facilities emitting 100,000 metric tons CO_2e or more per year in 2016 or a subsequent year. Opt-in provisions for (1) facilities competing against TIER-regulated facilities, or (2) facilities with annual emissions greater than 10,000 metric tons of CO_2-equivalent and designated as emissions-intensive and trade-exposed. TIER approved by Canada in December 2019.

Note: All emissions prices denominated in nominal Canadian dollars.

change is a clear collective action problem, even within a country. As a result, the political calculus in implementing a specific policy with 13 subnational jurisdictions means that, while cliché, the perfect is the enemy of the good. The federal government faced the trade-off of allowing flexibility and differences in policy within a given system, against a policy environment with 13 disparate systems (many of which involved little to no substantive action). Building on existing provincial plans allowed for greater buy-in among provinces. Moreover, this type of flexibility has precedent in other Canadian policy areas, such as health care.[5]

However, the policy convergence between 2016 and 2018–2019 was fleeting, and subsequent divergence is attributable to four factors. First, political preferences for regulation and subsequent rhetoric describing carbon taxes as a "tax on everything"; second, growing tension and public debate over resource development, emissions, and the public interest vis-à-vis oil sands growth and pipelines; third, federal-provincial negotiations over whether provincial plans would meet the minimum benchmark; and fourth, natural political shifts from electoral cycles. Combined, the broad cooperation on emissions pricing largely disappeared. As a result, only six of ten provinces had provincial systems approved by Canada. Others had the federal backstop imposed in part or in whole (two territories voluntarily adopted the federal backstop). Notably, visibly cooperative provinces secured exemptions in provincial policies that made the policies technically noncompliant with the federal benchmark, whereas non-cooperative provinces had the federal policy imposed (Dobson et al. 2019). A stark example is that Alberta secured an exemption for emissions from conventional oil and gas production (13 percent of provincial emissions [Dobson et al. 2019]). In contrast, Manitoba's plan called for a price of CAD 25 per metric ton on emissions, with no increases, instead of the federal price path. Manitoba's plan was not approved, and the federal backstop was imposed in full. The lesson here is that in implementing its policy, Canada chose to both "reward" cooperative provinces and "punish" non-cooperative ones.

The constitutional challenges of the *Greenhouse Gas Pollution Pricing Act* by recalcitrant provinces is an interesting example of the tensions of federal-provincial relations in an area of joint jurisdiction, and is relevant for this discussion. MacLean (2019) argues that these challenges have "very little to do with constitutional law doctrine" and are instead about climate politics in Canada. However, Newman (2019) notes that the justices in Saskatchewan and Ontario deciding in favor of federal jurisdiction had differing legal rationales for their decisions, making carbon pricing in Canadian federalism more complex than at first glance.

Despite the court challenges of federal power, carbon pricing is moving forward. New Brunswick had planned a constitutional challenge, but dropped those plans once the federal Liberals were re-elected in fall 2019 and has since had its provincial plan approved. Moreover, even Alberta, one of the most vocal opponents to the federal carbon tax, is keeping its large-emitter pricing system, which is in some instances more stringent than the federal large-emitter system. However, one can expect that if the Supreme Court of Canada ruled against federal jurisdiction, emissions pricing in Canada would substantially change. The lesson for other federal states is clear: in areas of shared jurisdictions, substantive policy action from the federal government requires support from subnational jurisdiction, although the reverse is not true.

[5] Canada has set a minimum standard and provides a per-capita transfer to provinces, and allows provinces to make independent spending decisions.

CONCLUSIONS

Emissions pricing in Canada is complex and politically contentious. Electoral cycles in Canada created a policy window for coordinated and substantive policy development on emissions pricing. This policy window, however, relied on pre-existing provincial policies as building blocks for federal policy. A key feature of implementation was preserving provincial independence in design, which meant a lack of uniformity across the country, both in terms of policy design and policy implementation. The policy window has closed, again due to electoral cycles. Permanence of pan-Canadian emissions pricing depends on whether Canada's Supreme Court rules in favor of federal jurisdiction (in the immediate term) and electoral cycles in the longer term.

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Subnational Carbon Pricing in the US

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INTRODUCTION AND BACKGROUND

The US has played an important role in addressing the global heating problem, although the intensity and direction of action to reduce national US carbon emissions has varied considerably over time – ranging from supportive (George Bush the elder, Obama) to strongly opposed (George Bush Jr. and Trump). Although early efforts at controlling carbon emissions nationally were bipartisan (e.g., the 2003 Climate Stewardship Act, sponsored by Republican Senator John McCain and Democratic Senator Joseph Lieberman), the issue turned partisan as soon as the Democrats embraced climate action with the election of President Obama in 2008. Reflecting this, the American Clean Energy and Security Act of 2009 (known as the Waxman-Markey bill) failed to be passed by Congress. From that point forward, climate action at the federal level has been modest and partisan (e.g., Obama's Clean Power Plan) to virtually nonexistent (Trump).

But the US is a federal system and states of the US have significant power, as do sub-state jurisdictions (counties and cities). In fact, states have always had a major role to play in air and water pollution regulation – the structure of Federal regulations relies heavily on federalism. The governing air pollution law, the 1963 Clean Air Act (and its amendments), specifically delegates the regulation of emissions from existing pollution sources to the states – the federal government sets goals for air quality.

Thus, it was natural that the challenge that emerged from the failure to regulate carbon at the federal level was taken up by some states. Keeping in mind that states are quite different from one another, the response has also been varied. California is a rich state with a strong environmental ethic, no coal and a fairly progressive electorate. Some Midwestern states have significant coal industries and by implication have a more politically difficult time supporting cuts to carbon emissions (which generally translate into reducing the use of coal in electric power generation). This explains why California, under the Republican governor Schwarzenegger, enacted the first major carbon reduction legislation in the country, the Global Warming Solutions Act of 2006 (known as Assembly Bill 32 – AB32). At approximately the same time (2005) several (now ten) northeast states banded together into the Regional Greenhouse Gas Initiative (RGGI), mutually agreeing to a cap and trade system for CO_2 from electricity generation. This reflects progressive traditions in these states.

If one reflects on what different countries are doing to curb emissions, why should there be any less incentive for action from a state like California with 40 million residents and an economy of size roughly on a par with major economies of Europe (rankings fluctuate with the exchange rate).

Market forces have also played a role in reducing carbon emissions. Figure 1 shows US carbon emissions over the past 30 years. Note that emissions peaked in 2007 and by 2018 had almost been reduced to 1990 levels, despite significant population and economic growth. A major reason for this is the technological advance of fracking, which has reduced the cost of extracting natural gas and oil, forcing out coal as an electricity generation fuel (see Kolstad, 2017).

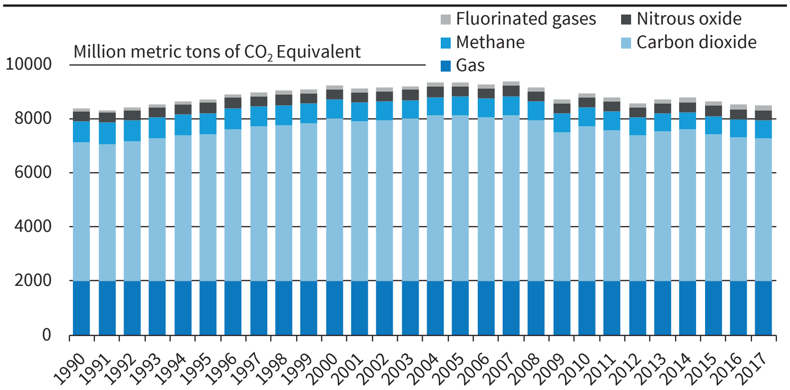
CALIFORNIA

California has a tradition of environmental leadership. Beginning in the 1940s, the state was plagued by smog. Although a mystery at first, eventually research pointed to the culprit – automobile emissions. As a consequence, the state began regulating emissions from automobiles in 1961 (National Research Council, 2006). A few years later the federal government enacted the Clean Air Act of 1963 and the Motor Vehicle Air Pollution Act of 1965. In 1970 President Nixon established the US Environmental Protection Agency. Also in 1970, the US Congress significantly strengthened the Clean Air Act, setting up the structure we have today of federal air pollution goals and state implementation plans for regulating local sources.

A commonly articulated reason for federal regulations as opposed to state re-

Figure 1

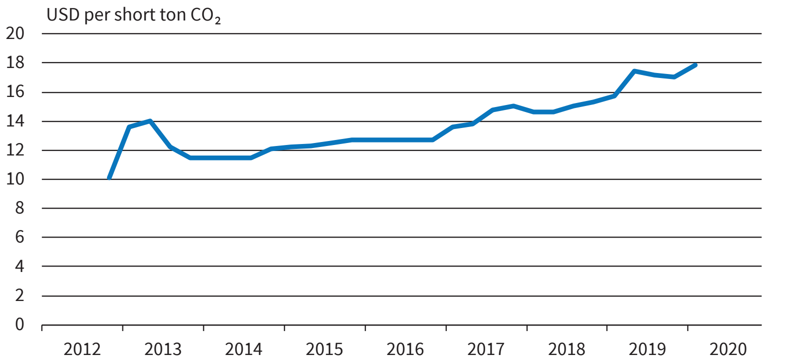
Gross Annual US Greenhouse Gas Emissions, 1990–2017



Source: US EPA Greenhouse Gas Data Explorer.

gulations is that commerce between states is easier with one national standard. In fact, the Clean Air Act prohibits states from setting different standards for automobile emissions. Thus the auto manufacturers need not worry about making a different car for every state. There is one exception: the law allows more flexibility to any state that had regulations on automobile emissions prior to 1966 (i.e., California). These states could apply for a waiver from meeting federal emissions standards, provided the state's regulations were at least as strict.

Figure 2
California Allowance Auction Clearning Prices, through February 2020



Source: California Air Resources Board. © ifo Institute

The point is that California has a tradition of being a leader when it comes to environmental protection – the federal government and other states typically follow California's lead. It is thus not too surprising that in the early part of this century (2002), California first ratcheted up fuel economy standards for new cars sold in the state. This was followed in 2006 by the setting up of a cap and trade system for reducing carbon emissions to 1990 levels by 2020.[1] Both actions were explicitly intended to address climate change. A debatable criticism levied at the California program is that it will cost a lot and have very little effect on global carbon emissions (because of the size of California as a proportion of the global market). But many supporters of the California initiatives argue that if the state can show that regulations can work without damaging the economy then it is likely other jurisdictions will follow suit. California regulations serve as a lever for other jurisdictions to reduce emissions.

The cap and trade program became operational in 2013, initially covering electric power generation facilities (including sources of power that are located out of state) and other large stationary sources. Gradually coverage was expanded to now include 85 percent of the state's emissions, including transportation fuels. Furthermore, the fraction of allowances freely allocated has gradually shrunk over time, with remaining allowances auctioned. The price of allowances is shown in Figure 2.

Through 2016 the auction reserve price was between \$12 and \$13 per ton, rising to just over \$15 in 2019. Note in Figure 2 that in early years of the auction, price was close to the reserve price (stipulated minimum bid) but over the past year, as the cap has tightened, the prices are beginning to diverge from the reserve price. We would also note that the price is lower than the EU ETS price (approximately USD 30 in February 2020[2]) but the gap is narrowing. However, both systems are generating prices that are significantly short of the social cost of carbon, at least as computed prior to the Trump administration revisions (i.e., approximately USD 40 per ton: Greenstone et al., 2013 and updates).

The California cap and trade system appears to be working well, though the real test will occur in the post-2020 period as the cap is ratcheted down. The goal for 2020 was to reduce emissions to 1990 levels. The goal for 2030 is 40 percent below 1990 levels. Unless the legislature relaxes this target, expect the price of allowances to increase significantly.

NEW ENGLAND RGGI

Although California has a long tradition of leadership in environmental protection, it was a set of New England states that moved before California to implement a greenhouse gas cap and trade system. The Regional Greenhouse Gas Initiative (RGGI) started in 2009 and originally covered the power sector in ten northeastern states (Schmalensee and Stavins, 2017). The goal was to limit growth in power sector carbon emissions through 2014 and then to reduce the cap so that 2020 emissions would be 13 percent below 1990 emissions. As discussed earlier, the dramatic drop in natural gas prices, coupled with the Great Recession created a surplus of permits. Consequently the cap was rethought in 2012 and tightened significantly, so that by 2020 the cap would be nearly one third lower than previously planned.

The effect of these actions can be seen in Figure 3. As with California, regular auctions are held, which allows the tracking of allowance prices. In the auctions there is a price floor, clearly seen as the flat section of prices for 2010–2013. There is also a price ceiling which has had virtually no impact yet. But

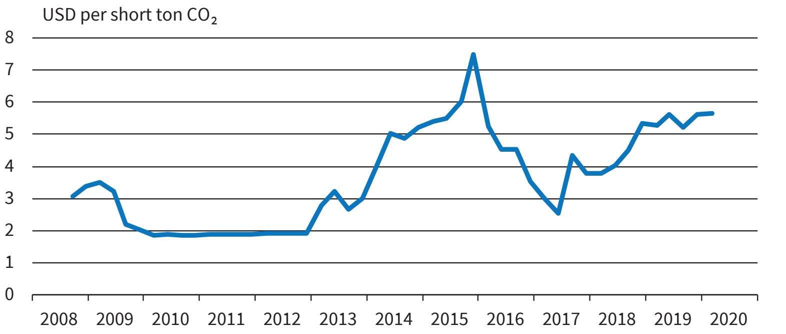
[1] The 2002, Assembly Bill 1493 (Pavely Regulations) tightened fuel economy standards in automobiles and in 2006, Assembly Bill 32 (Global Warming Solutions Act) established the cap and trade program.

[2] Business Insider reports a price of approximately EUR 24 per metric ton in late February 2020.

Figure 3

Regional Greenhouse Gas Initiative (RGGI) Allowance Clearing Price

Sep 2008–March 2020



Source: Regional Greenhouse Gas Initiative. © ifo Institute

what happens post-2020 could change that. Compared to the allowance price in California or the EU ETS or for that matter the social cost of carbon, the RGGI price is quite low. On the other hand, another conclusion is that even a price of under USD 10 per ton is sufficient to reduce emissions from the power sector significantly (with the help of low natural gas prices).

OTHER SUB-FEDERAL CLIMATE ACTION

The most significant other actions related to putting a price on carbon are failed attempts in the northwest part of the US. In 2016 Washington State tried what economists term a revenue neutral carbon tax of USD 15 per ton of CO_2, paralleling a successful carbon tax in neighboring British Columbia, Canada. Such a tax is often promoted as appealing to the politically moderate and in that sense is theoretically most likely to be politically accepted (due to the fact that the revenue generated is offset by a reduction in the sales tax). But some environmental groups opposed the initiative because of the lack of revenue which could have been used for pro-environment investments as well as helping groups which might be disadvantaged by the tax. The initiative failed with 60 percent voting against it. Another attempt was made in 2018, with the revenue generated targeted at financing specific projects, instead of returned via a sales tax reduction. The opposition to this initiative primarily came from the oil industry. The initiative was also defeated by 56 percent voting no.

Oregon has also been attempting to enact a cap and trade program for carbon, paralleling California's successful program. The effort has been opposed by Republicans, who have been creative in their opposition, at one point fleeing the state to prevent a quorum in the legislature. As this article goes to press, the Governor continues to push the legislation.

However, most action by states and localities in the US has been neither a carbon tax or a cap and trade system which induces a carbon price. Most actions are closer to command-and-control. This would include the widespread adoption of renewable performance standards for electric power, requiring a stipulated minimum amount of electricity used in a jurisdiction be generated by renewable sources; or incentives for adopting zero emission vehicles such as electric cars; or banning the use of natural gas in new home construction; or tightened building standards – to name just a few.

CONCLUSIONS

The most visible international action to slow carbon emissions has come from nations. It is nations that belong to the Framework Convention on Climate Change. It is nations that signed the Paris Agreement. It is nations that meet every fall for a Conference of the Parties to the Framework Convention. But action at the subnational level can be both easier to implement and effective in demonstrating proof-of-concept for the very tough problem of reducing carbon emissions.

One observation, supported by the failed initiatives in Washington State, as well as wrangling in California, is that voters are suspicious of carbon prices being used purely as incentives rather than revenue raising for a "worthy" purpose. But as more and more jurisdictions adopt some sort of carbon pricing, it may be that such opposition will soften over time.

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What Can We Learn from EU ETS?

In this paper we provide some context behind the EU's effort to implement EU-wide carbon pricing through EU ETS. Next, we discuss several lessons that could be drawn from this experience. Note that our focus is on EU ETS as the main vehicle for carbon pricing; other climate policies, including performance standards and subsidies for investment and innovation, remain largely untouched.

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IMPLEMENTING EU GHG EMISSIONS REDUCTION TARGETS THROUGH EU ETS

As agreed in Paris in 2015, countries should aim together to curb greenhouse gas (GHG) emissions to keep a global rise in temperature well below 2 degrees Celsius (United Nations 2015). This requires a very deep cut in GHG emissions as current levels would make a 3 degree rise in temperature in 2050 very likely. Carbon pricing is widely considered to be a crucial tool in reaching targets for deep decarbonization. Indeed, pricing ensures emission reductions at the lowest cost to society by offering flexibility in the choice of abatement measures and their timing.

Interestingly, GHG mitigation seems to be rather successful within the EU while the EU is also a pioneer in carbon pricing around the world. The EU (including the UK) shows an overall decrease of 21 percent in GHG emissions from 1990 levels by 2013. After an initial decline in the early 1990s, the reductions were largely attained in the aftermath of the economic crisis in 2008. Since 2014, GHG emissions have stabilized again. Nevertheless, the reduction reflects a breakthrough compared with the past, where economic growth correlates strongly with higher energy use and GHG emissions. Indeed, the GHG intensity of GDP fell by even more than 50 percent between 1990 and 2017.

A key instrument applied by the EU has been its explicit carbon pricing policy through carbon allowance trading within the EU Emissions Trading System (EU ETS) since 2005. This system covers around 40 percent of the EU's total GHG emissions and includes three European countries outside the EU. EU ETS is a typical cap-and-trade system inspired by the practical success of the US SO_2 cap-and-trade scheme in the 1990s (Burtraw and Szambelan 2009). Its main purpose is to reduce GHG emissions in a cost-effective way by providing a clear reduction pathway for industrial GHGs and to allow individual trades in carbon allowances between firms to find the cheapest abatement options.

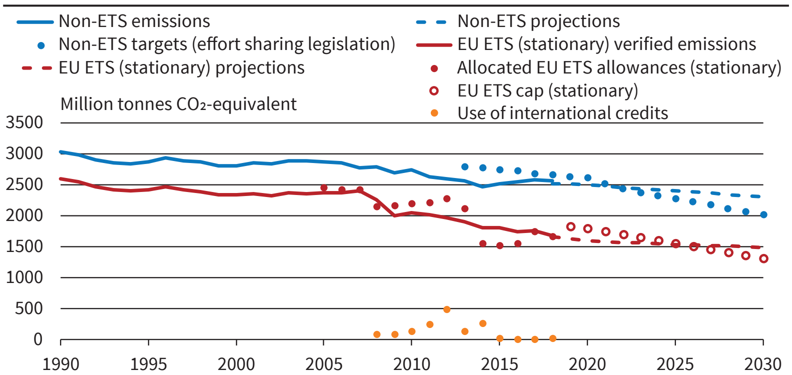
CARBON PRICING THROUGH EU ETS

A carbon cap-and-trade program like EU ETS internalizes the social costs of GHG emissions into (energy) market prices, which would also promote further investments in low-carbon technologies. EU ETS started with a "learning phase" from 2005 to 2007 and its design has evolved over the subsequent trading phases (2008–2012, 2013–2020, and 2021–2030). To date, EU ETS is the largest emissions trading scheme in the world (World Bank, 2019).

Figure 1 provides a concise picture of some key performance indicators for EU ETS emissions in the past as well as into the future. The figure shows a remarkably stable trend in emissions up to a strong decline in GHG emissions due to the economic crisis in the years 2008–2009. After the crisis, emissions never returned to their previous levels and decreased by an average 2.5 percent per year. The figure also shows an important gap between actual emissions and the allowance cap. Because of oversupply during the period 2009–2013, the allowance market built up a huge "bank" of allowances, i.e. allowances that are issued in earlier years but are unused and remain valid in later years as they have an infinite lifetime. Note that in 2013–2014 the bank exceeded a whole year of allowance supply.

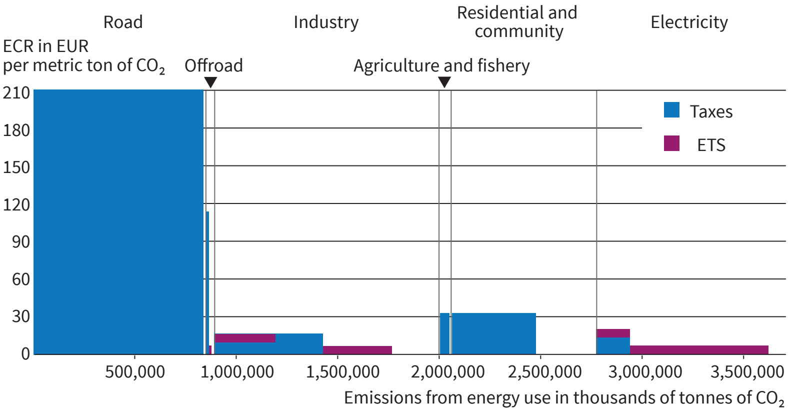
The decreasing cap (the dotted red line in Figure 1) reflects the ambition of the EU to reduce GHG emissions in the ETS sectors to zero in the

Figure 1
GHG Emisions in the EU28



Notes: Emissions from land use, land-use change, and forestry (LULUCF) and from international bunker fuels are excluded. Pre-2005 trends for EU ETS and non-ETS emissions are based on an allocation of 1990–2004 GHG inventory data to either the EU ETS or non-ETS sectors at source category level. EU ETS (stationary) emissions for the period 2005–2018 reflect verified emissions under EU ETS; emissions for the period 2005–2012 were estimated to reflect the current scope (2013–2020) of EU ETS.
Source: EEA (2019).

Figure 2
Carbon Pricing of CO_2
Emissions by sector and component, 2015



Note: Both tax base and rates are based on actual country-specific energy taxes.
Source: OECD.
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longer run. With the linear reduction factor as adopted in the revised EU ETS Directive of 2018, the supply of allowances will be zero in 2057. The decreasing cap implies that the cap will become more and more restrictive. The bank only helps to smooth the impact as it provides for intertemporal flexibility.

Figure 1 also illustrates the performance of EU ETS relative to the so-called non-ETS sectors. Various policy instruments contributed to a decline in emissions from these sectors, such as energy taxes, emission standards, and subsidies for energy efficiency improvements. However, this decline is less pronounced compared to EU ETS and even turned into a rise of emissions since 2014. Indeed, according to projections, additional reductions will be required in the 2020s. The flexibility mechanisms under the Effort Sharing legislation allow member states to sell part of their emission allocation for a certain year to another member state. Indeed, some member states, like Germany, are expected not to meet their non-ETS targets up to 2020 and will have to buy emission allocations from countries that have reduced emissions more than required.

Finally, the relevance of EU ETS for carbon pricing within the EU can be illustrated using effective carbon rates (OECD 2018). Using a highly disaggregated database of energy use and implicit carbon taxes as well as cap-and-trade information, the OECD presents a concise evaluation of how well the carbon emission base is priced (Harding et al. 2014). The analysis presents the rates on (fossil fuel) energy use in terms of carbon emissions. These effective rates do explicitly account for actual carbon taxes, specific taxes on energy use, and tradable emission permit prices in the various countries and consider the share of emissions priced at various levels. Emissions for which tax rates are zero are also included in the calculation. Figure 2 presents this graph for the whole of the EU.

According to this analysis, EU ETS prices most, though not all, carbon emissions in the power sector and about 60 percent of those in industry. EU average tax rates for road transport and in the residential sector, recalculated based upon their underlying carbon intensities, are generally much higher.[1] These higher rates, in particular the mineral oil products gasoline and diesel used in the transport sectors, should also be linked to other externalities, however, such as air quality impacts (Parry and Vollebergh 2017).

FIRST LESSON: THE CAP

After the “learning by doing” pilot of the first trading phase (2005–2007), a key step in setting a cap for the EU has been the gradual change from national allocation plans to a common overall approach where EU legislation guarantees the cap to be reduced annually by roughly 38 million allowances in the third trading phase (2013–2020). This corresponds to a so-called linear reduction factor (LRF) of 1.74 percent of the average total quantity of allowances within the EU. This factor has even been further increased to an LRF of 2.2 percent in 2018, which would guarantee zero additional carbon allowances in 2057.

Setting the level of the cap and its development over time is by far the most important element of cap-and-trade policies. The cap limits the overall quantity of emissions and therefore guarantees – like (enforced) standards – the effectiveness of the environmental policy. To what extent this trajectory fits optimal climate policy, however, cannot easily be derived from a simple cost-benefit evaluation of climate policy. Good reasons exist to evaluate the trajectory against policy goals as agreed upon internationally, such as the Paris agreement of 2015 (see e.g., Heal and Milner 2014).

A very important step forward has been the change from a fixed to a flexible duration of the value of an allowance starting from the second trading phase onwards. Consequently, firms were able to bank their allowances for use in subsequent trading periods. A look at Figure 1 shows that demand for allowances throughout the second period was below

[1] Note that the figure reflects the relatively low rate for the EU ETS in 2015. ETS prices have increased significantly since 2018 (see also Figure 3).

Figure 3
Futures Prices EU ETS Allowances

Notes: Non-adjusted Euro price based on spot-month continuous contract calculations.
Source: ICE (ECX EUA Futures prices, Continuous Contract #1). © ifo Institute

the allocated allowances and a very large bank of allowances built up. The bank is almost equal to the total supply of allowances in 2018 and allows for intertemporal flexibility at the carbon allowance market but does not change the overall amount of emissions that are capped during the entire period in which the policy is effective.

A related issue has been the allowance of "offsets," i.e., the option to allow additional emissions if they could be offset through international credits provided by the Clean Development Mechanism (CDM) and Joint Implementation (JI). This way, credits for more than 1 billion metric tons of CO_2 equivalents have been surrendered in phase 2, which has been an additional factor explaining the overallocation and therefore the growing lack of scarcity during the second period (see also Verdonk et al. 2013). Moreover, the contribution of CDM projects to actual emission reduction is challenged as well (Ellerman et al. 2015). Although offsets can be an important tool to provide flexibility for outside options, such as low-cost abatement projects, their use should be carefully managed, as the impact of CDM has shown.

The first important lesson is that a cap-and-trade system like EU ETS is very helpful in guaranteeing a credible and binding reduction of emissions within the ETS sectors. The gradual yearly reduction of allowances is a key element to deliver its promised contribution to a long-run deep decarbonization within EU ETS, whereas no such guarantee would be provided by using a carbon tax instead. Trust in the system is essential and the fact that EU ETS is firmly established in European law is very helpful and guarantees its participants the rule of law. Further ambitions, such as expressed by the European Green Deal, are best implemented by increasing the LRF. Also, prudence in using offsets is essential as the experience within EU ETS has not been convincing.

SECOND LESSON: TRADE

The second key element of any cap-and-trade system is the option for individual firms to trade. In other words, with enough scarcity in the market, trades will occur between those who have a surplus of allowances and those who are in actual need for compliance at a given point in time. Indeed, the overall supply determines the number of allowances becoming available for trade, but trading between market participants occurs only if buyers need allowances for short-run compliance or long-run hedging. Indeed, trade has been much easier since the change that meant allowances remain valid indefinitely. Banking strongly increases market liquidity as this allows for the possibility to trade against future expected emissions and firms can individually optimize compliance over their entire planning horizon (Ellerman et al. 2015).

For almost the entire phase 2, EU ETS has suffered from a lack of scarcity, however. In addition to the economic crisis in 2008–2009 and the use of international credits, the impact of renewables and energy efficiency policies also played a role here (Koch et al. 2014). Both energy efficiency improvements and an increased share of renewable energy reduce demand for allowances because energy use and the generation of electricity were mainly fossil fuel based. National policies supporting the deployment of renewable energy technologies in the EU have also been an important driver of emission reductions in the EU ETS sector electricity (Van den Bergh et al. 2013).

Due to this relative lack of scarcity in the carbon market in phase 2, prices were rather low for a very long time (see Figure 3). This collapse of the carbon price ignited a heated debate to neutralize the lack of scarcity in the market (see also Ellerman et al. 2016). In particular, support grew for the idea of introducing a minimum price or even a price collar within EU ETS (e.g. Burtraw et al. 2010). Policymakers in the EU followed another approach by setting up quantity-based interventions, such as backloading and the so-called Market Stability Reserve (MSR) agreed upon in 2018.

The idea behind the MSR can be summarized as a quantity-based rule: if the total number of allowances in circulation is

- less than 400 million in a year, then the MSR releases 100m allowances into circulation in the following year;
- between 400 million and 833 million, then the market functions without any release or absorption;

– greater than 833 million, then the MSR will reduce the volume of allowances auctioned in the subsequent year by 12 percent of allowances in circulation (note that during the first years of operation, i.e., 2019–2023, the absorption rate will be 24 percent).

The core impact of the MSR is its governance of the excess quantity in the bank of allowances. This feature will reduce the overall supply of allowances by a substantial amount if the bank gets "too large."

The MSR reform invoked a heated debate among economists about its impact and effectiveness. Some argue that the MSR's core feature would make the EU ETS emissions cap a function of market outcomes (Perino et al. 2019). Others suggest that the MSR would inevitably lead to a new Green Paradox and increase total emissions (Gerlagh et al. 2019). To what extent the MSR quantity-based mechanism will have an impact on the overall amount of allowances is not easy to judge, however. One should be very careful when deciding against what counterfactual to evaluate its impact.

As shown by Perino et al. (2019), the supposed impact of the MSR rules depends on the points in time when the MSR is predicted to become effective and stops taking in allowances when the bank is depleted "enough." Demand for allowances, however, is notoriously difficult to predict. Not only do uncertain macroeconomic developments have an impact, but also overlapping policies and assumptions on the carbon abatement cost in the future. It should not come as a surprise that estimates for allowance cancellations in the literature range from 2 billion to 16 billion allowances (Perino and Willner 2017; Bruninx et al. 2019).

Whatever the outcome of the debate, the MSR reform has already had an impact on the carbon price in practice. Since the MSR together with the stricter LRF were implemented into European law in 2018, allowance prices have surged up to EUR 25 on average in 2019 (see Figure 3). This suggests that the market expects future scarcity to increase, which casts its shadow through this price hike. Such an impact would have been unlikely if the market believed that these measures would be ineffective. In other words, the impact of the new MSR rules is relevant but should also not be exaggerated. Moreover, the rules of the MSR itself are subject to updating because the MSR will be reviewed in five-year intervals.

The lesson on trade is that providing enough flexibility in a cap-and-trade system is essential but should also be guided with care. Intertemporal trade is key to a well-functioning market but might also lead to low prices if allowances are abundant. Additional measures in such circumstances are unavoidable for the system to remain a credible instrument for carbon pricing and to have impact on current market and future investment decisions. We believe that for newly introduced cap-and-trade systems, some degree of hybridity is essential, either through a price collar or quantity rules such as the rules in the MSR. Both mechanisms help to steer cap-and-trade programs in the event of unexpected shocks and unanticipated overlapping policies, although a price collar has the advantage of more transparency.

THIRD LESSON: COVERAGE WITHIN THE OVERALL CLIMATE PRICING POLICY APPROACH

Figure 2 illustrates that EU ETS is an important cross-cutting tool for pricing carbon from the use of fossil fuels within the EU. Its carbon price "base" covers most emissions within the electricity sector and in energy-intensive industry. Indeed, the idea was originally to limit EU ETS to large combustion installations only, such as installations with a total rated thermal input exceeding 20 MW. Including smaller installations would become too costly in terms of transaction cost and taxes on mineral oils already account for the implicit pricing of carbon in the so-called non-ETS sectors (see also Vollebergh et al. 1997).

This hybrid approach towards using two different policy instruments for carbon pricing is occasionally challenged. For instance, the European Green Deal of the European Commission argues for including the maritime sector in EU ETS (EC, 2019). Some economists go much further and argue in favor of extending EU ETS to the transport sector (Hepburn and Toytelboym 2017; Creutzig et al. 2010).

The idea of an upstream inclusion of transport fuels into ETS has the benefit of simplicity in providing an EU-wide instrument to guarantee equal carbon abatement costs across the economy. Indeed, carbon emissions are directly linked to the carbon content of transport fuels, mainly mineral oils. Extension would be easy by including upstream refineries and importers of refined fuels into the system.

Extensions make sense for sectors that are not yet subject to any carbon price, such as shipping and, previously, air transport. Although an (implicit) carbon tax on fuel or kerosene would be a good alternative, inclusion in EU ETS certainly improves welfare. Less obvious, however, is to see why such a policy would be preferable if fuels are already subject to an implicit carbon tax.[2]

First, Figure 2 shows that including transport fuels and other sectors in ETS would result in a much larger overlap of existing (implicit) carbon pricing policies. Overlapping instruments may have strong negative impacts on both effectiveness and

[2] The overall welfare impact of such a carbon price reform policy would depend on both incentives and transaction costs, which, in turn, also depend on both upstream and downstream abatement options and cost. Note that the subsequent reasoning does not apply to the inclusion of intra-EU flights in EU ETS since 2012, as kerosene was largely unpriced.

efficiency. Using an applied CGE model, Brink et al. (2016) show how (additional) EU carbon taxes simply crowd out the cap-and-trade policy if the two policies interact on the same carbon emission base.

Second, if the emissions trading system for the transport sector will replace existing fuel taxes, most likely the carbon price of fuel use will decrease, as current fuel taxes are much higher than the price of EU ETS allowances. Given the relatively high marginal cost of reducing emissions in the transport sector, it will be more attractive to buy allowances than to reduce emissions. This would shift abatement from the transport sector to other sectors covered by EU ETS, increasing fuel use and making electrification of cars more difficult.

Third, such a switch would also increase local air pollution. Extending EU ETS to road transport would make the ETD redundant from a carbon policy perspective. However, fuel taxes cannot be removed totally, as member states still use their fuel taxes for other transport-related externalities such as air pollution and congestion (Parry and Vollebergh 2017).

One could wonder why the current boundaries of carbon emissions associated with large combustion within EU ETS should in any case be changed. The tendency in several non-ETS sectors is towards electrification, such as electric cars or the use of (electric) heat pumps. This development is the result of targeted policies in those sectors, such as the gradual rise in stringency in the EU-wide fuel standards for car companies. Moreover, expanding electrification will shift demand away from mineral oils to electricity, which is already covered by EU ETS.

The lesson on coverage of sectors is that the choice to focus on large installations makes a lot of sense from an overall welfare perspective. It is far from obvious why EU ETS should cover the entire carbon emissions base. Including small-scale installations and other hard-to-monitor individual emitters might simply be too costly if other instruments, like (implicit) carbon taxes and standards, are already available. This argument holds even if potential upstream options, such as the inclusion of implicit emissions through refinery products, are available.

FOURTH LESSON: IMPACT ON CARBON EMISSIONS, LEAKAGE, AND INCREASED EFFORTS

The EU ETS cap guarantees reductions in carbon emissions in the long run as it settles a carbon budget within the EU over time. This budget is enforceable as long as the system is kept intact, even though its flexibility allows actual carbon emissions to be different from the annual emissions cap in a specific year. Indeed, the overall trend in carbon emissions within the EU over the last decade is decreasing, as Figure 1 demonstrates. This overall downward trend follows from the decreasing emissions trend within the EU ETS sectors, in particular the electricity sector.

It is still unclear to what extent EU ETS has contributed to this downward trend. In particular, the increased deployment of renewable energy technologies boosted by national policies, often in the form of feed-in tariffs and premiums, has likely been the primary driver in emission reductions in this sector. However, EU ETS also increased the cost of carbon-intensive production and it may have contributed by encouraging short-run fuel switching from coal to natural gas (Delarue et al. 2010) and by changing long-run expectations of returns on investments in carbon-intensive projects.[3] Dechezleprêtre et al. (2018) find evidence for carbon emission reductions through EU ETS in the order of − 10 percent between 2005 and 2012 by comparing installations whose production capacity is above the inclusion threshold (and therefore became regulated by EU ETS) with those that are below the threshold but are otherwise similar. In addition, Calel and Dechezleprêtre (2016) show that EU ETS has increased low-carbon innovation among regulated firms.

These trends do not show the potential impact of EU ETS on carbon leakage. Carbon leakage occurs if a reduction in domestic carbon emissions is offset to some extent by increasing emissions in countries where climate mitigation policy is absent or less stringent. According to several studies, such leakage impacts can be substantial (Böhringer et al. 2010; Bollen et al. 2012). Empirical estimates also suggest a gradual shift of carbon gravity towards countries like China and South Korea (Aichele and Felbermayr 2012). Although developed countries have reduced their territorial emissions, this effect is at least partially offset by importing embodied carbon (UNEP 2019). Such carbon leakage poses a serious threat to uncoordinated climate policies, not only in the EU but also in other developed countries.

Leakage issues become even more pressing if one looks at recent EU efforts to align its efforts with the ambitions of the Paris agreement. The imposition of stricter measures on EU carbon emissions to aim at worldwide net zero carbon emissions in 2050 has recently received a boost by the EU initiative of a Green Deal. This initiative is strongly supported by a growing number of EU member states who advocate for EU climate policy to be more ambitious, or by a coalition of the willing of intra-EU member states at least.

It is important, though, to understand that despite several efforts to cap worldwide GHG emissions, such as the Kyoto protocol in 1997, overall yearly GHG emissions have doubled since 1990 and the global trend is still upward instead of downward. An exception in this world of growing emissions, however, is the EU. Despite a yearly economic growth

[3] Note also that EU ETS has an impact on the effectiveness of renewables policies: a carbon price reduces the cost difference between fossil-fuel-based electricity and electricity from renewable energy sources (Verdonk et al. 2013).

of 1.8 percent, emissions of GHGs declined annually by 0.9 percent on average between 1990 and 2018. Nevertheless it is still a challenge to continue this trend into the future, as Figure 1 illustrates. Furthermore, even with the increased LRF of 2.2 percent agreed upon in 2018, GHG emissions within EU ETS will still be somewhat higher than the level required for carbon neutrality in 2050 while the EU ETS price is well below the discounted social cost of carbon for 2020 (OECD 2018).[4]

Whatever the initiative for further emissions reductions, any additional measures on top of existing EU policy would benefit strongly from better coordination of international carbon pricing policies or, in the absence of such coordination, by implementing policies such as border price adjustments to prevent a carbon race to the bottom. Such coordination is particularly important for exposed industries such as the manufacturing industry that are part of EU ETS. Currently, the risk of carbon leakage from EU ETS is addressed by free allocation of allowances to industries that are vulnerable to competition from outside the EU. And some member states compensate companies for the increase in electricity costs due to EU ETS.

The lesson here is that carbon pricing through EU ETS has contributed to the clear downward trend in carbon emissions within the EU, although subsidies for cleaner electricity generation have played a large role as well. However, we also observe a gradual tendency to outsource emissions to other regions, which consequently increases the carbon footprint of our consumption. With further initiatives to increase stringency ahead, it is a logical next step to invest more resources in a carbon border adjustment mechanism for selected sectors to ensure that the price of imports will more accurately reflect their carbon content and to reduce the risk of carbon leakage.

CONCLUSION

The EU is aiming for climate neutrality by 2050. For this purpose, stricter carbon pricing policies seem to be key. With its clear reduction pathway for CO_2 emissions up to 2030 and beyond, EU ETS provides firms a clear and credible incentive to reduce emissions. Indeed, EU ETS is the only instrument currently implemented within the EU framework on climate and energy policy that imposes a hard limit on carbon emissions and guarantees the application of a carbon emissions budget. While allowing participants to also trade their allowances, however the system also provides a cost-efficient way of reducing GHGs from a variety of large sources.

Empirical studies confirm that EU ETS contributed to emission reductions as well as innovation in low-carbon technologies even when the carbon price was relatively modest. After years of relatively low allowance prices, however, the recent revision of the EU ETS directive contributed to an unprecedented price rise, with the price also likely to rise even further in the future due to the decreasing cap. Higher carbon prices will further promote investments in technologies that are required for the EU to achieve its long-term target of a low-carbon society by 2050.

Extending coverage of EU ETS to current non-ETS sectors such as transport or buildings is a less obvious step for us. Most of fossil fuel-based heating and motor fuels will gradually give way to electricity. If this electricity is generated by fossil fuel-fired power plants, the associated emissions will be covered by EU ETS, and otherwise the impact on carbon emissions is clearly positive. Instead of focusing on the extension of EU ETS towards non-ETS sectors, efficient carbon policies seem to benefit much more from efforts to align existing implicit carbon taxes with the broad set of externalities relevant for these combustion processes.

[4] In its recent study the OECD also includes a price reference rate to explore so-called carbon pricing gaps (OECD 2018). The carbon pricing gap not only includes price base gaps but also takes into account an estimated social cost of carbon.

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Pricing Carbon at the Border: Key Questions for the EU

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With the nationally determined contributions (NDCs) by parties to the 2015 Paris Agreement, governments are naturally focused on what they can do unilaterally. Coordinated policies like joint compliance and international emissions trading are proving to be thorny issues and a point of failure in the Conference of the Parties (COP25) in Madrid. This uncoordinated landscape of divergent carbon prices with limited geographic and sectoral coverage allows scope for international trade to undermine the effectiveness of unilateral carbon-pricing regimes through carbon leakage.[1] Furthermore, fear of adverse competitiveness effects can hamper political support for strong action. Although the share of annual global greenhouse gas (GHG) emissions subject to carbon pricing continues to expand, prices remain relatively low (World Bank and Ecofys 2019). As a result, little actual carbon leakage has been observed thus far (Dechezlepretre and Sato 2017). Nevertheless, some jurisdictions that price carbon (or are planning to do so) attach measures to level the international playing field – for example, by offering free allocation of emissions allowances to industries at risk of leakage. To date, that practice has arguably resulted in substantial overcompensation of firms in the EU (Martin et al. 2014); however, ratcheting up ambition also requires ratcheting down free allocation, leaving little maneuvering room to use compensation to address leakage as carbon prices climb.

Pricing carbon at the border by introducing border carbon adjustment (BCA) is another tool for addressing carbon leakage. The BCA tool has two parts that could level the playing field for producers in high-carbon-price countries. One is to require comparable payments for the emissions embodied in imported goods (import adjustments), to help ensure that consumers face consistent prices for the carbon content of the products they buy. The other is to relieve exported goods of their embodied emissions costs (export adjustments), to keep domestic exporters on an even footing abroad. BCA may also be viewed as a lever to encourage trade partners to improve their carbon footprints. Several prominent economists and political scientists have promoted trade measures as a means for supporting carbon pricing "climate clubs" (e.g., Victor 2011, p. 245; Nordhaus 2015; Gollier and Tirole 2015).

Although the concept of BCA – shifting towards consumption-based carbon pricing – is straightforward and intuitively appealing, its design and implementation are challenging in practice. In particular, a policymaker crafting BCA provisions must make numerous, complicated regulatory choices, including scope of applicability (i.e., which policies, goods, sectors, countries), methodology for assessing the carbon content of products, type and price of the adjustment, exemptions or modifications for products from any specific countries, and use of the resulting revenues. Each of these choices has economic and environmental implications that influence the effectiveness of the BCA, as well as nuanced technical, legal, and political consequences.

In this article, we summarize some recent reviews of the scholarship on BCA (Cosbey et al. 2019; Mehling et al. 2019) and how the ideas may apply to emerging policies.[2]

WHO IS CONSIDERING BCA?

The European Union has an ambitious climate agenda under its Green Deal (European Commission 2019). It plans to deepen decarbonization in order to increase mitigation targets for 2030 and achieve climate neutrality by 2050. Carbon pricing under the EU Emissions Trading Scheme (EU ETS) will therefore need reform leading to a higher carbon price; other policy tools like energy taxation and investment schemes will be integrated into the agenda. The proposed mechanism for BCA could be the inclusion of imported goods in the EU ETS, a customs duty, or a border "tax." The latter option could be legally compatible with World Trade Organization (WTO) rules if a new EU energy taxation directive introduced carbon intensity as a tax base across the EU as a whole. The European Commission has issued a first proposal for new legislation with a mechanism that "would counteract this risk [of carbon leakage] by putting a carbon price on imports of certain goods from outside the EU" (European Commission 2020).

The EU is not alone in its attraction to border measures. Nearly every example of draft climate legislation circulating in the US Congress includes BCA. For example, the Climate Leadership Council, a US group of conservative policymakers and economic advisers, developed a bipartisan climate roadmap that describes a plan for carbon taxation with lump-sum rebates. This "carbon dividends plan" includes

[1] We define carbon leakage as the increase in emissions in foreign jurisdictions that can be attributed to the implementation of a climate policy (particularly carbon pricing) in the home jurisdiction. It is distinct from the broader concept of global trade in embodied carbon, where carbon-intensive production tends to shift towards developing countries and return as imports to industrialized countries (Peters et al. 2011).

[2] Ismer et al. (2020) also discuss policy options for the EU, including an alternative ("behind the border") design of combining free allocation with a consumption charge based on the same benchmark. Morris (2018) and Flannery et al. (2018) discuss BCA options from a US perspective.

a full BCA proposal: export rebates as well as import fees would accompany a national carbon tax (Baker et al. 2017; Climate Leadership Council 2020). Mexico has mentioned BCA in its NDC, and others are likely to follow in considering BCA – or responding to one. Therefore, the EU bears some responsibility if it acts first, and it should proceed with an eye towards the global evolution of carbon pricing, consulting with trade partners all along the way.

WHY USE BCA?

The primary objective of BCA must be to reduce carbon emissions. Indeed, the protection of a global resource is the only objective fully consistent with WTO exceptions in cases where BCA design does not meet basic WTO principles (Horn and Mavroidis 2011). Economic modeling finds that BCA can reduce carbon leakage rates by one-third to one-half (Böhringer, Balistreri, and Rutherford 2012; Balistreri and Rutherford 2012; Branger and Quirion 2014). By passing carbon costs through to consumers, BCA tends to be more cost-effective than other unilateral options, such as targeting vulnerable energy-intensive trade-exposed (EITE) sectors with exemptions (Böhringer, Carbone, and Rutherford 2012) or output-based allocations (Fischer and Fox 2012a). This advantage tends to get stronger as climate ambition increases (Böhringer, Fischer, and Rosendahl 2014). BCA may also encourage some exporting countries to tighten their climate policies to improve their market access (Böhringer, Carbone, and Rutherford 2016; Irfanoglu et al. 2015; Lessman et al. 2009); however, the tariff levels in WTO-compatible BCA are unlikely to be sufficient to bring many pollution-intensive countries into a carbon-pricing coalition (Nordhaus 2015; Bednar-Friedl et al. 2012; Weitzel et al. 2012).

By addressing competitiveness-related leakage, BCA can improve the political acceptability of pricing carbon emissions from domestic producers. However, BCA is not a panacea for EITE industries because they could use carbon-intensive intermediate inputs from unregulated regions or face weaker domestic demand from rising prices (Böhringer, Carbone, and Rutherford 2012; Burniaux et al. 2013).

WHEN CAN BCA BE APPLIED?

To adhere to WTO principles of non-discrimination, countries cannot ask for more or different compliance from importers than they ask of their own firms producing comparable products. That means that only price-based climate policies can be associated with a price at the border. A domestic carbon tax can be complemented by a border tax. For an emissions trading system, the border adjustment would likely entail compliance with the purchase of emissions allowances, with similar options for acquisition and time horizons for compliance as those enjoyed by domestic producers.

Economically, this principle makes sense as well. As Cosbey et al. (2019) explain, fundamentally, BCA requires importers to pay for the carbon embodied in their products – that is, the emissions associated with their production – and thus incentivize abatement. Non-price-based policies like performance standards may also encourage abatement, but they do not require that producers pay for the remaining embodied carbon. Price-based policies also have a transparent cost of carbon that forms the basis for the border charge. Implicit cost estimates are not valid for adjustment, not only because they can be manipulated (and nonmarket policies are likely to lead to inefficiently high marginal abatement costs) but primarily, again, because of the lack of pricing of embodied carbon.

WHAT GOODS WOULD BE ELIGIBLE FOR BCA?

BCA should be applied when there is significant risk of carbon leakage. Sector eligibility should rest on a combination of two criteria: carbon cost exposure and trade exposure (Fowlie and Reguant 2018; Sato et al. 2015). The EU has established a process to identify its at-risk sectors in the carbon leakage list, which it uses for free allocation. Whether the specific thresholds the EU used for a sector's direct and indirect carbon costs and its trade intensity with non-EU countries are ideal can be debated, but the two criteria are good indicators of which sectors need consideration. The EU 2020 proposal for BCA suggests beginning with one or two sectors (e.g., cement or steel) as a way to prove the concept before expanding to other sectors.

Several factors suggest that restricting coverage to imported goods from core EITE sectors is best. Legally, export rebates are difficult to defend because they could fall under WTO restrictions on so-called prohibited subsidies. Moreover, subsidies do not qualify for the environmental exceptions available to justify tariffs and import regulations under Article XX of the General Agreement on Tariffs and Trade (GATT) (Cosbey et al. 2019). The economics literature is also mixed on the effectiveness of export adjustments. Economically, most of the leakage mitigation benefits are obtained when BCA is applied only to imports of major EITE sectors (Böhringer, Carbone and Rutherford 2012). Broad application of BCA to all products and all embodied emissions does little to improve (and may even reduce) cost-effectiveness (Böhringer, Carbone, and Rutherford 2018).

HOW WOULD BCA BE CALCULATED?

Calculating emissions content requires first determining a system boundary – that is, what emissions to include – and then calculating a benchmark. The system boundary can be drawn narrowly, for direct emissions only, or broadly, with all emissions along the supply chain or life cycle. An intermediate option would capture direct emissions and primary indirect emissions from power production, the main sources of carbon costs for the at-risk sectors. Importantly, the system boundaries cannot include more emissions than are subject to carbon pricing for implementing country producers, and the EU ETS covers only direct emissions and primary indirect emissions.

If the BCA covers both direct and primary indirect emissions, a default carbon intensity for each must be determined. In the EU ETS, a benchmarking exercise has already been conducted for domestic sources for the free allocation of emissions allowances. However, BCA requires a determination for foreign sources. The decision whether to use actual emissions data or a sector-wide benchmark involves trade-offs amongst firm incentives, industry incentives, data collection, compliance costs, and WTO obligations. Basing the calculation on actual emissions (or providing the option to certify them) is the only way to confer incentives for foreign exporters, on the margin, to reduce their emissions. However, such firm-specific calculations are administratively onerous and subject to reshuffling of emissions. For example, the market could simply reallocate the lowest-carbon production for sales to the EU, while higher-carbon production remains for unregulated consumption. Alternatively, the calculations could be based on more readily accessible data. For example, using the domestic average emissions intensity of a sector would arguably avoid discriminating by country, which could seem more in the spirit of WTO rules, as would a best-available-technology measure, although that would offer weaker leakage protection. A related question is whether to differentiate by production process (e.g., steel made using emissions-intensive coke or steel made from scrap steel using an electric arc furnace powered by renewables).

A hybrid approach could use a common sectoral emissions intensity for direct emissions and a country-specific measure for indirect emissions, for which data is available from national reporting. This option would potentially give foreign countries some incentive to improve their performance and thereby lower the burden on their exporters, but it would differentiate by country of export and require strong transshipment provisions. Overall, little economics research has been done to quantify the importance of reshuffling or the magnitude of incentives for foreign producers or regulators. In any case, allowing producers to provide third-party-verified firm-level data on emissions intensity would improve the odds that a BCA scheme is found legal (Cosbey et al. 2019).

WHERE MIGHT WE MODIFY OR EXEMPT THE ADJUSTMENT?

Ideally, and to comply with GATT exception provisions, the BCA would also offset the differential between foreign and domestic price-based climate policies.[3] Of course, if the foreign system has a different compliance mechanism or system boundary than the domestic system, this adjustment may require more than simply calculating the difference in carbon tax rates or certificate prices.

A BCA system must also recognize any free allowances or other compensatory mechanisms enjoyed by domestic firms and offer comparable benefits to imports covered by the BCA. In some cases, the BCA level may need to be adjusted down to zero. Generally, BCA should not be combined with other cost compensation behind the border (i.e., applied to domestic products) because such compensation would undermine the case for a GATT exception and would increase the likelihood of illegal subsidization. For symmetry, adjustment for foreign carbon prices must account for free allocation abroad.

An alternative to adjusting the BCA based on country-specific factors is the provision of a wholesale exemption, which is equivalent to modifying the emissions benchmark to zero. Indeed, case law suggests that it may be illegal to demand specific policies as a basis for exemption from BCA, rather than requiring that the exporter achieve some given level of climate performance.[4] Country-based exemptions also have the potential to unfairly discriminate amongst exporters and may thus be incompatible with GATT's requirements, but they might be justified under GATT's exception provisions if they contribute to protecting the environment. The use of such country-based exceptions is included in the EU proposal.

There are five possible exemptions on a country basis:

1. *Exempting countries that implement a national emissions cap.* Because an effective national cap theoretically precludes leakage, it would be allowed under GATT (Cosbey et al. 2019). However, many emissions caps are not as strict as the EU's, thus allowing for leakage.
2. *Exempting countries that take "adequate" national actions other than national caps.* As indicated above, non-price-based mechanisms should not be eligible for border adjustment, so the case for exempting them is unclear. Importantly, any national climate regime other than a hard cap

[3] For the same reasons that BCA should not be allowed for sectors or products that are regulated with non-price-based policies, such policies in the foreign country should not generate adjustments to the BCA.

[4] The Appellate Body in *US – Shrimp* ruled against a US law for demanding that foreign shrimp fishers use exactly the same equipment as US fishers to avoid the incidental capture of turtles.

is susceptible to leakage. Defining ex ante what constitutes adequate action is also difficult. On the other hand, not using this exemption may violate GATT's exception provisions concerning arbitrary treatment of exporting countries, if the exporting country is party to the Paris Agreement. The latter could be interpreted as international recognition of adequate national actions, but the diverse NDCs indicate a lack of clear consensus on adequacy.

3. *Exempting sectors from countries that implement a sectoral cap.* If a country effectively caps a given sector's emissions, no sector-level leakage will occur. Adjustments for sectoral carbon pricing (or export taxes) could also be included in the BCA calculations.
4. *Exempting least-developed countries and low-income countries.* This may help the measure align with the UNFCCC principle of common but differentiated responsibilities (CBDR) and the WTO principle of special and differential treatment. The exemption would not hurt the effectiveness of BCA in preventing leakage, since very few of these countries export EITE goods.
5. *Exempting countries by means of administrative flexibility.* Public policy objectives might motivate exemptions, but they must lead to predictable criteria. Administrative simplification, for example, can be more useful than BCA modifications for avoiding double charging or for aligning with CBDR goals.

Given those considerations, exemptions should be incorporated into a BCA regime with caution. Any differentiation based on the country of origin raises transshipment and reshuffling problems. Transshipment provisions work best when the goods in question are wholly obtained in a single country or at least have a very simple supply chain. Thus, if exemptions are sought, they seem more compatible with a narrow BCA that covers only a small number of commodity-oriented EITE goods.

HOW SHOULD THE REVENUES BE SPENT?

Revenues collected from import charges raise opportunities but also create an obligation to demonstrate that the primary goal of the policy is to reduce emissions, not to protect domestic industry. Earmarking to support low-carbon investments in domestic sectors is one idea, but even though it supports the environmental goal, it also can be seen to serve as additional protection. The fact that BCA tends to shift the burden of climate policy towards developing countries (Böhringer, Fischer, and Rosendahl 2010) runs counter to the principles of CBDR. Alternatively, dedicating the revenues to benefit the exporting countries can avoid this shift or even make exporting countries better off (Böhringer, Balistreri, and Rutherford 2012; Fischer and Fox 2012b). Not retaining the revenues also removes domestic incentives to use the BCA to manipulate the terms of trade. Thus, dedicating the revenues to objectives that assist developing countries can improve a BCA regime's chance of success in meeting GATT's exception requirements by helping to demonstrate good faith.

CONCLUSION

The EU is considering whether to prevent carbon leakage by adjusting the carbon price at the border. Amongst the unilateral options to address leakage, BCA may be the most efficient, but it is also the most controversial and legally challenging. Setting up such a tool will require EU policymakers to determine the coverage of traded goods and their emissions, develop a transparent calculation of the BCA, recognize carbon pricing in the countries of origin, consider the overall climate ambition of trade partners' NDCs, and comply with WTO rules. The central aim has to be effective performance in preventing emissions leakage.

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Carbon Pricing in Switzerland: A Fusion of Taxes, Command-and-Control, and Permit Markets

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Like other European Nations, Switzerland has signed the Kyoto Protocol and the Paris Agreement. Not being part of the European Union, however, it has pursued a different approach to climate policy than the rest of Europe. The cornerstone of Swiss climate policy is carbon pricing, but this comes in three versions that involve different actors and carry different price tags. In addition, a number of support schemes are in place, e.g., for the development of renewables and insulation of buildings. In this article, however, we focus on Swiss carbon pricing.

Switzerland has one of the highest carbon taxes in place worldwide. Currently, this tax is CHF 96 per ton of CO_2 equivalent.[1] The tax is levied on fossil fuels as they cross the Swiss border. However, there are important exemptions. Importantly, the tax applies to combustion fuels but not to transportation fuels. There are ongoing discussions in the Swiss parliament about extending carbon pricing to the transport sector, which is responsible for a third of total greenhouse gas emissions in Switzerland, and which is the only sector where emissions have remained constant (FOEN 2020).

With the aim of protecting the interests of energy-intensive firms, the Swiss government has introduced two programs that allow firms to be exempt from the CO_2 tax. The first was established in 2008 and can be described as a collaborative command-and-control instrument coupled with an abatement subsidy. To join the program, firms in energy-intensive industries subject themselves to a set of specific abatement measures and emissions targets that are developed in cooperation with energy experts. If a firm's emissions are below its target in a given year, it can sell the difference as "over-abatement" for a fixed fee. This program is known as "nonEHS"[2] and currently includes around 1,200 firms.

The second exemption program is an emissions trading scheme, which was introduced in 2013 and currently includes 53 plants. The system is called CH EHS and has been designed to link it with the European Union's Emissions Trading Scheme (EU ETS). Due to lengthy political negotiations, the linking of the systems was delayed for several years, but it finally took place on January 1, 2020.

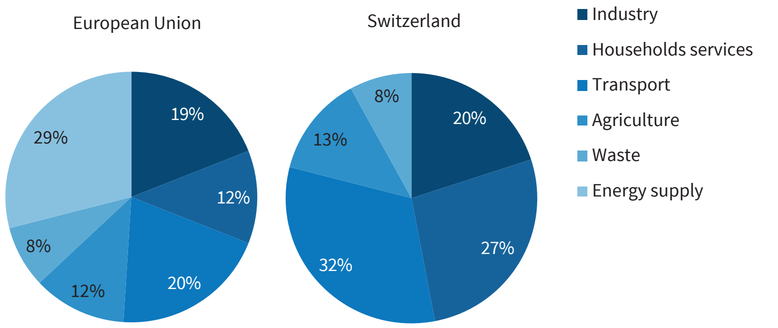
In this article, we describe the three competing carbon pricing programs that co-exist in Switzerland and the limited information that is available about their effects on emissions. We furthermore provide preliminary results about the relati ve effectiveness of the CH EHS and nonEHS programs based on our ongoing work.

THE CO_2 TAX

Swiss climate policy is based on the Federal Act on the Reduction of CO_2 Emissions ("CO_2 Act"),[3] which has been updated several times since its inception in 2000. Originally, the CO_2 Act focused on meeting the Kyoto Protocol commitment of overall GHG emissions reductions of eight percent during the 2008–2012 period, relative to the 1990 baseline. There have been a number of updates to the CO_2 Act, and it is currently in the process of revision to shape climate policy after the year 2020. The agency in charge of implementing the CO_2 Act is the Swiss Federal Office for the Environment (FOEN). For additional scientific and political background related to Swiss climate policy, see Brönnimann et al. (2014).

Figure 1 shows the sectoral distribution of GHG emissions in the EU and in Switzerland. This difference in the emissions portfolio is important for understanding the diverging approaches to climate policy. Emission trading schemes are well suited for large, stationary emission sources such as power plants. Because Switzerland has only few installations that are large enough to be in-

Figure 1
Sectoral Emissions in the EU and Switzerland



Source: Swiss Federal Office for the Environment; European Environment Agency. © ifo Institute

[1] At the time of writing, the Swiss Franc (CHF) is close to par with the US Dollar (1 CHF = 1.03 USD).

[2] EHS is the German acronym for Emissionshandelssystem, or emissions trading system. The system is called nonEHS to differentiate it from the CH EHS.

[3] This is known as the "CO_2 Gesetz" (SR 641.71). For more information, see https://www.admin.ch/opc/de/classified-compilation/20091310/index.html.

Table 1

Fuel Prices and CO_2-Related Surcharges

		Unit	2008	2009	2012	2014	2016	2018
CO_2 tax		(CHF/tCO_2)	12	24	36	60	84	96
Heating oil EL	Market price	(CHF/kg)	0.990	0.560	0.894	0.766	0.385	0.612
	Surcharge	(CHF/kg)	0.038	0.076	0.114	0.190	0.265	0.303
Natural gas	Market price	(CHF/kg)	0.519	0.240	0.394	0.334	0.201	0.347
	Surcharge	(CHF/kg)	0.032	0.064	0.096	0.160	0.224	0.256
Hard coal	Market price	(CHF/kg)	0.158	0.076	0.087	0.069	0.058	0.090
	Surcharge	(CHF/kg)	0.028	0.057	0.085	0.142	0.198	0.227
Propane	Market price	(CHF/kg)	0.836	0.510	0.811	0.617	0.286	0.532
	Surcharge	(CHF/kg)	0.036	0.072	0.108	0.179	0.251	0.287

Note: The market prices reflect international exchange prices and do not include the Swiss CO_2 tax.

Source: Prices from Thomson Reuters Datastream (Heating oil: Gasoil 0.2% sulphur FoB ARA; Coal: API2 Cif ARA; Gas: TTF; Propane: North Sea NWE FoB). Surcharge computed based on emission factors from FOEN.

cluded in an ETS, its main climate policy instrument is the CO_2 tax.

The CO_2 tax on fossil heating and process fuels was introduced in 2008. It is collected by the Federal Customs Administration at the border crossing (there are no fossil fuels produced in Switzerland). Two-thirds of the collected revenue is redistributed to households (on a per capita basis) and to firms (in proportion to their payroll). The remainder is used to pay for a building energy efficiency program and a technology fund. The tax was introduced at a level of CHF 12 per ton of CO_2, along with a set of interim abatement targets. Compliance with these targets is assessed periodically, and non-attainment triggers an automatic increase in the CO_2 tax in multiples of CHF 12 per ton of emissions. Table 1 shows the tax rate evolution, along with the prices for some of the most important fossil fuels.

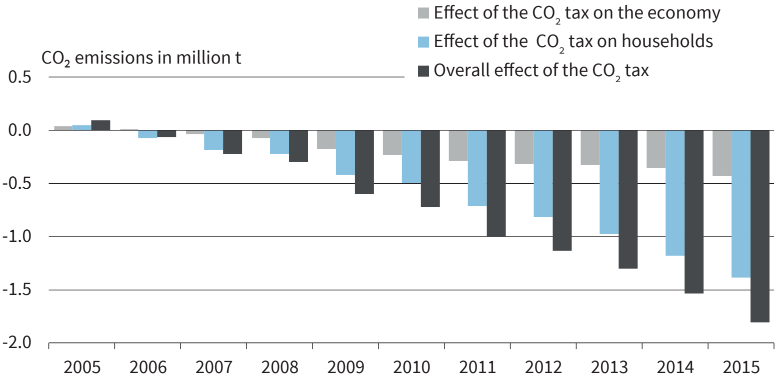
It is difficult to measure the effectiveness of the CO_2 tax. Since everyone is affected either by the levy or one of the two exemption programs, no control group exists that could provide a credible counterfactual. Furthermore, the fuel use of firms and households subject to the tax is only recorded on aggregate because the levy is imposed at the border and simply becomes part of the total price. Individual quantities of fuel use are recorded only for firms that are exempt from the tax.

The most recent quantitative analysis of the effect of Swiss CO_2 tax on emissions is by Ecoplan (2017). This study estimates the effect of the CO_2 tax on firms and households by means of a time series analysis. The authors conclude that from 2008 to 2015, the tax led to a reduction of 6.9 million tons of CO_2, which corresponds to 4.4 percent of the relevant combustion emissions during that period. Figure 2 shows the emissions reductions based this model. The estimated effect of the tax increased over time. In 2015, the reduction was computed as 1.8 million tons, corresponding to just over 10 percent of the relevant emissions. About two-thirds of the reduction is due to households, whereas the remainder originates from firms that are not exempt from the tax.

These results rely on the assumption that the time trend (capturing demographic changes, technological progress, etc.) before the introduction of the tax also applies to the period after 2008, and that no important drivers of emissions are included. Both assumptions are essentially not testable. For example, if issues related to climate change became more salient during the Kyoto period of 2008–2015, then the trend in the absence of the tax may have steepened, which would lead to an overestimate of the effect. If, on the other hand, unobservable variables (such as a shift in demand unrelated to the tax) led to a relative increase in emissions, then the effect of the tax would be understated. At any rate, the tax appears to have an effect, whatever its exact size, and this effect increases as the tax is adjusted upwards.

Figure 2

Emission Reductions as Computed by Ecoplan



Notes: The solid line shows the results obtained by the time series analysis, and the dashed line those from the CGE model. The vertical axis measures the reduction in CO_2 emissions in million tons.

Source: Ecoplan (2017) in collaboration with EPFL and FHNW.

THE CH EHS

The Swiss Emissions Trading Scheme (CH EHS) was introduced in 2013. By 2018, it included 53 plants that together emitted 4.577 million tons of CO_2 (FOEN 2019a). According to the Swiss Greenhouse Gas Inventory (FOEN 2020), this accounts for 27 percent of the emissions from combustion that are subject to the CO_2 Act and for 13 percent of total emissions in Switzerland. By sector, the largest emitters are cement plants, followed by plants in the chemical, refining, district heat, metal, and paper sectors. The majority are mandatorily included in the CH EHS, whereas four additional plants have opted into the system.[4] More details about the CH EHS are provided by FOEN (2018a). In what appears to be a design flaw, CH EHS firms received some of the redistributed revenue from the CO_2 tax (along with households and small firms), despite being exempt from it (EFK 2017).

The cap is set relative to the Kyoto period and reduced by an annual factor of 1.74 percent (this corresponds to the reduction rate in the EU ETS). EHS firms receive most of their emission allowances allocated for free. The distribution of free allowances across sectors is guided by harmonized allocation rules based on the benchmarks of emissions performance. Five percent of the annual cap is retained as a reserve for new entrants, whereas the remaining 95 percent is distributed at no cost. Plant closures lead to an adjustment of free allocation but not of the total cap, as these allowances are added to the reserve. Any unused allowance reserve is auctioned in the following year. Figure 3 shows the cap, free allocation, and emissions in the CH EHS.

As no secondary allowance market has emerged in Switzerland, the clearing prices from the biannual auctions are the only price signal available in the CH EHS. The auction prices are shown in Figure 4, along with the price of EU allowances. Despite the planned linking of the two systems, the price in the CH EHS does not closely track the price in the EU ETS for much of the sample period. A likely reason for this is the absence of a secondary market, making it difficult for financial intermediaries to exploit arbitrage opportunities between the Swiss and European carbon prices. Firms in the CH EHS were allowed to cover some of their emissions using international offsets, which further contributed to the system's over-allocation and to the low auction prices. The recent increase in the allowance price is most likely due to the reforms in the CH EHS and the linking that took place in January of this year. Despite the over-allocation and the low financial incentives to abate, however, emissions in the CH EHS did decrease over time, as can be seen in Figure 3. In 2018, the total emissions within the CH EHS were 17 percent lower than in 2013. A part of this decrease may have been due to the fact that many of the included firms face additional command-and-control measures at the cantonal level.

[4] These are plants owned by firms that also have other plants in the CH EHS.

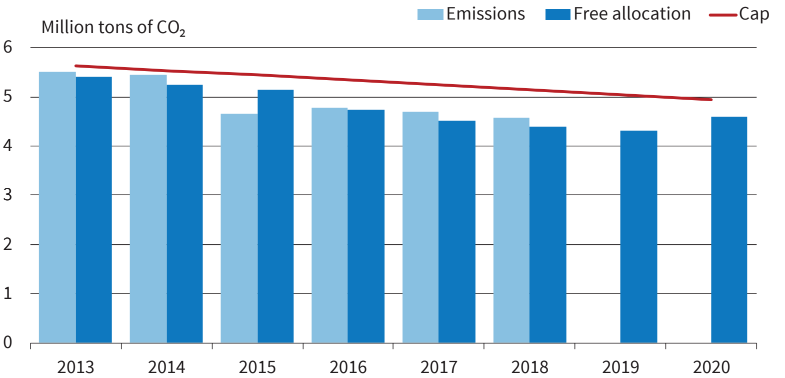
THE NONEHS PROGRAM

There are three conditions a firm must meet in order to be eligible for the nonEHS program: First, it must belong to a pre-defined set of energy-intensive industries. Second, its emissions must not be too large, as otherwise it would be included in the CH EHS (see above). And third, its emissions must not be too low. More specifically, if a firm has a sufficiently large installed heat capacity or emits at least 100 tons of CO_2 per year, it can apply for an exemption from the CO_2 tax.[5] The process of exemption from the CO_2 tax is shown in Figure 5.

There are two subtypes of the nonEHS program. In the first, firms agree to subject themselves to a particular set of abatement measures, whereas in the second, they additionally agree to specific emissions targets. Both the abatement measures and the emission targets are developed in close cooperation with energy experts from the Energy Agency of the Swiss Private Sector (EnAW) and the Cleantech Agency Switzerland (act). The proposed measures and targets are then submitted for approval to FOEN. Only the abatement measures and emission paths that are deemed "economically viable" are included in the agreement, thus ensuring that firms are not forced to engage in very costly

[5] This inclusion threshold is currently being revised. According to the most recent proposal by the Swiss senate, firms are eligible to join the nonEHS program if their CO_2 tax expenditure exceeded CHF 10,000 in the previous year. As the CO_2 tax increases, this means that the inclusion threshold in terms of emissions is lowered.

Figure 3
Cap, Emission and Free Allocation in the CH EHS



Information about the cap available at https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-policy/emissions-trading/swiss-emissions-trading-scheme--ets-.html.
Source: FOEN (2019a).
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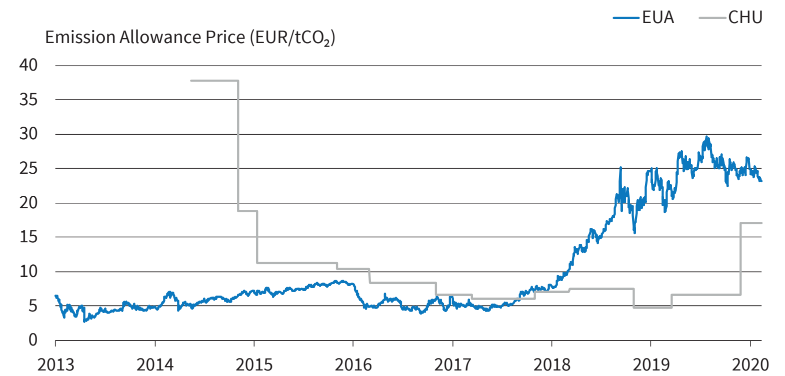
Figure 4

Allowance Prices in the CH EHS and the EU ETS, 2013–2020



Note: The EUA prices are daily, whereas the CHU prices only change in bi-annual auctions. The conversion rate is 0.94.

Source Bundesamt für Umwelt (2020).

abatement measures.[6] In 2018, the number of firms in the nonEHS program was 659, of which 505 had explicit emission goals, whereas the remaining 154 firms were subject to specific abatement measures (FOEN 2019b).

Firms are legally required to carry out the agreed measures and to reach their emission targets in order to be exempt from the CO_2 tax. The nonEHS program is therefore a firm-specific command-and-control approach. Such an approach could, in theory, perform as well as a market-based measure in terms of aggregate abatement costs, and even outperform it if the process of defining the abatement measures informs firms about their available options. On the other hand, developing firm-specific measures and targets can be costly. Since firms pay for the services provided by EnAW and act, the costs to the government accrue in the form of lost revenue from the CO_2 tax. Table 2 shows emissions and the foregone tax revenue by year. Through 2018, the total loss in tax revenue was CHF 1,017 million.

In addition to the foregone tax revenue, the government actively subsidizes firms to over-comply. If participants in the nonEHS program reduce their emissions by more than what is mandated in their agreement, they can sell the surplus in the form of certificates to a government-owned fund. The rate at which the certificates were purchased ranged between CHF 40 and CHF 100 during the first five years of the program but has been fixed at CHF 100 since 2013.[7] Through 2018, the total amount of over-compliance was 3.8 million tons of CO_2, which corresponded to a total subsidy payment of CHF 296 million (column 5–6 in Table 2). In addition to the foregone revenue and the subsidy costs, the nonEHS also has administrative costs as FOEN regularly needs to monitor and verify compliance of all participating firms (Rütter soceco 2016).

The effectiveness of the nonEHS program in terms of emissions reductions is difficult to assess, both in absolute terms (as there is no untreated control group) and relative to non-exempt firms (as no emissions information is available for the latter). To obtain indicative results, we can refer to two sources. The first is a report commissioned by FOEN (TEP Energy 2016), which surveyed firms subject to the tax or one of the exemption mechanisms with respect to climate-relevant decision-making. Exempt firms reported that they carried out more measures for emissions reductions than firms paying the tax. However, large firms and firms with a high emission intensity were more likely to both seek exemption and to engage in significant abatement measures. This self-selection of "motivated" firms into the nonEHS program means that we cannot assign a causal interpretation to these results.

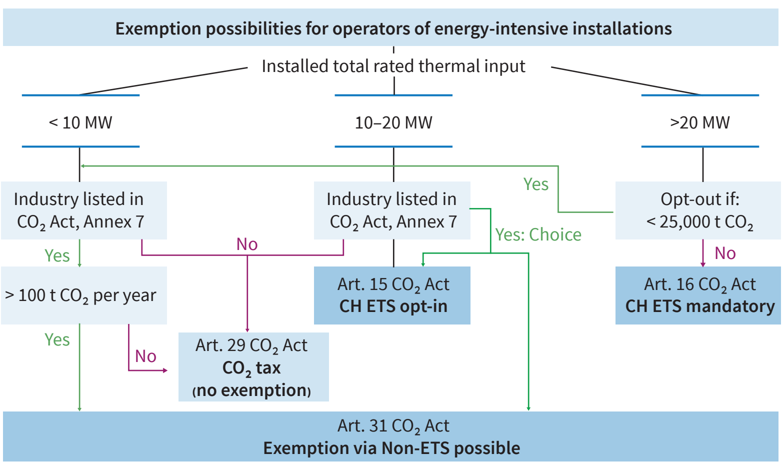
Second, we can focus on engineering estimates pro-

[6] For production and processing facilities, a measure is deemed economically viable if the investment pays for itself within four years, based on the investment cost and the energy prices, including the CO_2 tax. For investments in building insulation and heating equipment, the required payback-period is eight years (FOEN 2018b, p. 80).

[7] If firms exceed their emissions goal, they can cover up to eight percent of their emissions using international offsets (FOEN 2018b). No firm in the program emitted in excess of 108 percent of their emission target.

Figure 5

Exemption Possibilities for the Swiss CO_2 Tax



Source: Translated from the Swiss Federal Office for the Environment: https://www.bafu.admin.ch/bafu/de/home/themen/klima/fachinformationen/klimapolitik/co2-abgabe/befreiung-von-der-co2-abgabe-fuer-unternehmen.html

Table 2

Emissions, Lost Tax Revenue, and the Value of Subsidies Paid to nonEHS Firms

Year	Emissions (Mt CO_2)	Tax (CHF/tCO_2)	Revenue loss (Million CHF)	Offset amount (Mt CO_2)	Offset value (Million CHF)	Government cost (Million CHF)
2008	2.95	12	35.4			
2009	2.70	24	64.7			
2010	2.89	24	69.4			
2011	2.77	24	66.6			
2012	2.69	36	96.7			
2013	1.57	36	56.7			
2014	1.49	60	89.3			
2015	1.62	60	97.4			
2016	1.65	84	138.9			
2017	1.67	84	140.7			
2018	1.68	96	161.4			
2008-2012	14.0		332.7	3.1	220.7	553.5
2013-2018	9.7		684.3	0.8	75.4	759.7
Total	23.7		1'017.1	3.8	296.1	1'313.2

Notes: The offset amount and value is only available by compliance period, not for individual years.

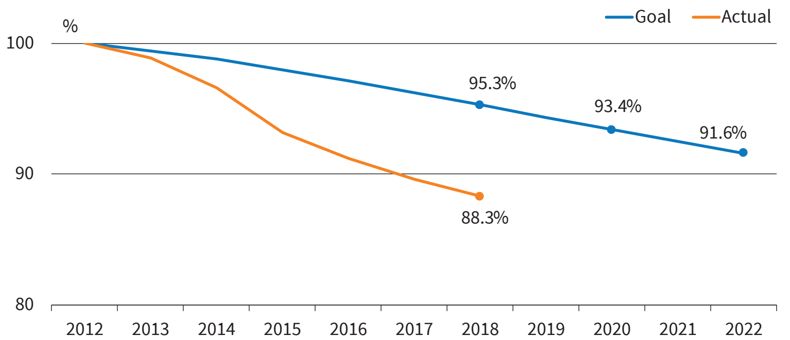
Source: Authors' calculations.

vided by EnAW (2019) that are the basis for determining the abatement measures and emissions goals. Figure 6 shows the target emissions path for nonEHS firms (blue line) and their actual emissions (yellow line), both indexed to 2012. This graph suggests that the nonEHS program was responsible for an emissions reduction of 11.7 percent between 2012 and 2018. However, it is not clear that the engineering estimates appropriately reflect the emissions in the absence of the nonEHS program, because some the abatement measures would probably also have been carried out if firms were subject to the CO_2 tax or in the course of general technical change. For example, the installation of LED lights is the most frequent abatement measure agreed to by firms, but LED lighting is becoming ubiquitous. In general, it is not clear that the agreed measures are additional in the sense they would not have happened if firms had to pay the tax. After all, implementing these measures would currently reward non-exempt firms by CHF 96 per ton of emissions, and this value is set to further increase in the future. For this reason, not all of the emissions reductions implied by the EnAW model can be interpreted as the effect of the nonEHS program per se.

Figure 6

Reduction Goals and Over-Compliance in nonEHS

CO_2-Intensity



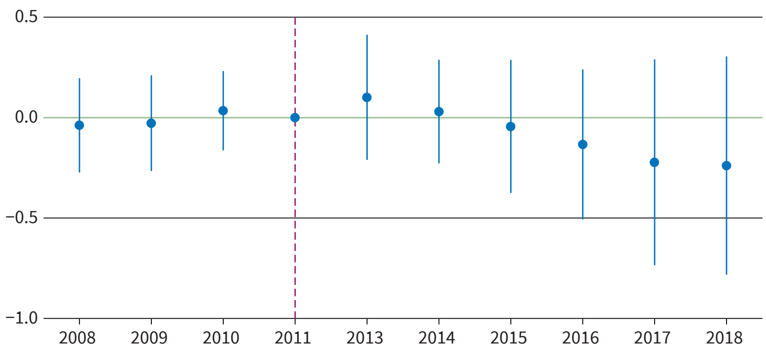
Source: ENAW (2019). © ifo Institute

THE DIFFERENTIAL IMPACT OF THE EHS VS. NONEHS PROGRAMS

As mentioned above, it is impossible to cleanly identify the effect of either the tax or one of the exemption programs due to data availability. What is feasible, however, is to compare the effect of the EHS vs. nonEHS programs on emissions. In an ongoing and yet unpublished study, we focus on firms that were part of the nonEHS program in 2008–2012. A subset of these firms was transferred to the CH EHS in 2013, whereas the others remained in the nonEHS program. This allows for the identification of the differential effect of these programs using a "difference-in-differences" framework. Because nonEHS firms receive CHF 100 for every ton of CO_2 that they abate, whereas EHS firms obtain only the value of an allowance (which is much less), we expect nonEHS firms to engage in a greater effort to abate emissions than EHS firms. To ensure comparability across years, we focus only on emissions that were regulated throughout the sample period.[8]

[8] We restrict the emissions to "regular" fossil fuels. In contrast, process emissions have been regulated only since 2013, along with emissions associated with process heat and waste.

Figure 7
Differential Treatment Effect on Emissions (EHS vs. nonEHS)



Note: To generate this figure, we regressed the log of firm emissions on a set of firm fixed effects, year fixed effects, and year by treatment interaction dummies. The points in the graph show the coefficient estimates on these interaction dummies. The year 2012 was removed due to anticipation effects. The bars represent 95 percent confidence intervals.

Source: Hintermann and Zarkovic (2020).

Figure 7 shows the differential treatment effect on emissions (EHS minus nonEHS) by year. Although we do find a positive coefficient (i.e., a lower abatement effort) for a subsample of EHS firms, the average effect for the full sample is close to zero and not statistically significant. The results suggest that the nonEHS program may be no more effective than a regular EHS in terms of reducing emissions. However, we stress that this is work in progress.

DISCUSSION

Switzerland exempts firms in energy-intensive sectors from paying the carbon tax with the argument of protecting their competitiveness and thus saving domestic jobs. Whereas the introduction of the CH EHS is consistent with EU climate policy, the tax and the nonEHS program are special to Switzerland. This program benefits firms in two ways: (i) They do not have to pay the CO_2 tax, and (ii) they receive a subsidy for reducing their emissions below an emissions target that was not particularly stringent. It is thus not surprising that industry representatives favor this program and would like to see a reduction in the threshold to join, but it is also clear that the nonEHS program imposes significant costs on society. Between 2008 and 2018, the monetary costs from the foregone revenue and the subsidy payments amounted to CHF 1.3 billion, and additional costs accrue every year in the form of monitoring and compliance. These costs have to be compared to the benefits of the program.

Whereas firms in the nonEHS program indeed reduced their emissions, the available empirical evidence does not imply that the program per se was more effective in terms of abating emissions than the CH EHS or the tax. This is not surprising from an economics point of view as the opportunity costs of emitting CO_2 are identical for a tax and a subsidy of equal size: If a firm in the nonEHS reduces emissions by one ton, it receives the subsidy. If a firm subject to the tax reduces emissions by the same amount, it saves the tax. The marginal incentive to reduce emissions is therefore the same, so it is not clear why the nonEHS program would be expected to perform better in terms of emission reductions. Whether it has saved jobs is not obvious either given the high level of employment in Switzerland. In any case, we are not aware of any empirical work that investigates the employment effects of the nonEHS.

Proponents of the nonEHS argue that there is a value of informing firms about available abatement options and providing expertise (e.g., via agencies such as EnAW and act). We very much agree, but this expertise could also be provided without a tax exemption, because firms should be interested in reducing emissions to avoid paying the tax. By 2018, 266 firms had used the energy consulting services from EnAW to define voluntary emissions targets without becoming exempt from the tax (EnAW 2019). A different argument holds that firms pay more attention to money they can earn than to tax payments they can avoid. This is possible subject to some behavioral assumptions, but such a clear preference for realizing gains rather than avoiding losses should materialize in measurably greater emissions reductions by nonEHS firms relative to firms in the CH EHS. However, we do not find this to be the case in our ongoing work.

For these reasons, we argue that current proposals to reduce the inclusion threshold for the nonEHS program should be considered with caution. Exempting more firms from paying the tax not only adds to the regulatory cost, but it further concentrates the burden of climate policy on households and small firms in exchange for uncertain benefits. We believe that distributional concerns should be considered when fighting climate change and that energy-intensive firms are expected to share at least some of the cost of climate policy.

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The Flexcap – An Innovative CO_2 Pricing Method for Germany

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THE CURRENT DEBATE ABOUT A CO_2 PRICE

The past year has been marked by an extensive public debate about the introduction of a uniform CO_2 price in Germany.[1] On September 20, 2019, the federal government decided to introduce a national CO_2 price. It opted for a price regulation, which will be replaced by quantity regulations from 2026 onward. This article proposes an alternative approach that combines price and quantity targets from the outset, thus creating planning security without losing sight of the quantity target.

The German government's decision consists of a combination of two mechanisms which, as discussed below, lie at opposite ends of the possible spectrum: direct price control through a CO_2 tax on the one hand and direct quantity control through an emissions trading scheme on the other. Formally, a national emissions trading system for the heating and transport sectors is to be set up in 2021, with an annually increasing, predetermined price for certificates for first five years.[2] Companies subject to the scheme may purchase an unlimited number of certificates at this fixed price. This will give Germany a pure price control for the first five years, which will have the same effect as a CO_2 tax. From 2026 onward, the quantity of available certificates is to be limited in accordance with the German climate targets.[3] A CO_2 tax will therefore be replaced by emissions trading in 2026. According to the federal government, this switch between instruments is intended to guarantee companies and consumers price security initially, while at the same time ensuring compliance with the climate targets in 2030.[4] In this article we present the "Flexcap," a mechanism that combines the advantages of a tax and an emissions trading system in a single system.

A part of the greenhouse gas emissions (GHG) in Germany is already regulated by an emissions trading system: the European Emissions Trading System (EU ETS).[5] The EU ETS covers around 45 percent of total emissions across the EU; in Germany, the energy, industry, and construction sectors covered by the EU ETS accounted for as much as 57 percent of total emissions in 2017 (SVR 2019). The current debate therefore focuses on GHG emissions that are not covered by the EU ETS, particularly in the transport and heating sectors. In the transport sector, emissions have hardly decreased since 1990. This is also problematic because there are binding reduction targets for the non-ETS sectors under the "EU Effort Sharing Regulation." By 2030, Germany must therefore reduce its GHG emissions in these sectors by 38 percent compared to 2005 levels. If this is not achieved, substantial compensation payments to other EU countries may be required.

For this and other reasons, policymakers, scientists, and the public seem to agree that a CO_2 price should be introduced as well for the non-ETS sectors (e.g., Blum et al. 2019). Concerning implementation, the federal government had obtained several expert opinions prior to September's decision (BMWi 2019; SVR 2019; DIW 2019). These agreed that, at least in the longer term, efforts should be made to extend the EU ETS to all sectors in all EU Member States, an objective that will be politically difficult to achieve and implement in the short to medium term. In a transitional period, pricing CO_2 requires a solution at the national level (or in a "coalition of the willing"). This article presents a solution that combines the advantages of pure price and quantity regulation and is therefore more efficient: the so-called Flexcap. In the longer term, such a solution could also be established for the EU ETS or other emissions trading schemes. In order to place this proposal in the context of the current debate, it is helpful to recall the alternatives discussed prior to the government's decision: a CO_2 tax and an emissions trading scheme.

CO_2 TAX

A CO_2 tax is levied on every ton of CO_2 emitted. If a company can reduce its CO_2 emissions by using certain technologies, it will save money by avoiding emissions for which the costs of these technologies – the so-called "abatement costs" – are lower than the tax. The remaining emissions are subjected to the tax. The same applies in an emissions trading scheme if the quantity of allowances is not limited but can be purchased at a fixed price, as decided by the federal government. The price of the certificates

[1] A component of this debate is the distributional effect of such CO_2 pricing. This question is orthogonal to our proposal and not part of this article. For a discussion in the German context, see for example DIW (2019).

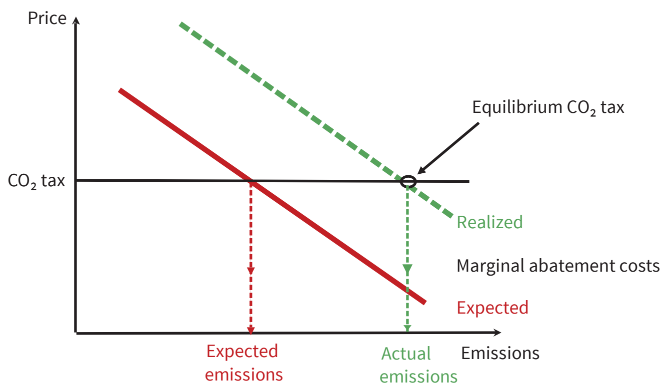
[2] The price in 2021 will be EUR 25/tCO_2, and will increase to EUR 55/tCO_2 in 2025.

[3] In 2026, a price corridor of EUR 55-65/tCO_2 will be introduced, which allows the targeted emission quantity to be exceeded if the price is too high.

[4] However, this is not guaranteed due to the the upper price limit: when it is reached, additional certificates and thus emissions are generated until their price is EUR 65 again. In this case, Germany would not comply with its obligations to the EU and would have to compensate the other states for this with considerable financial sums.

[5] For more information on the EU ETS, see Schmitt et al. (2017) and Weimann (2017).

Figure 1
CO₂ Taxes



Source: Authors' illustration.

corresponds to the tax rate. The amount of emissions realized thus depends on the level of the tax and the (marginal) abatement costs. However, the actual level of abatement costs is subject to considerable uncertainty. If the abatement costs realized by companies and households are higher than anticipated by the regulator, a given tax leads to more emissions than expected (see Figure 1). Under such a price regulation, there is uncertainty about the amount of emissions generated, which may lead to considerable deviations from a reduction target (BMWi 2019). Under the planned national emissions trading scheme, the federal government therefore has no control over the total emissions of the heating and transport sectors in the first five years (2021–2025). In order to meet the climate targets for 2030, a system change to actual emission trading (with a price corridor) is planned for the end of 2025.

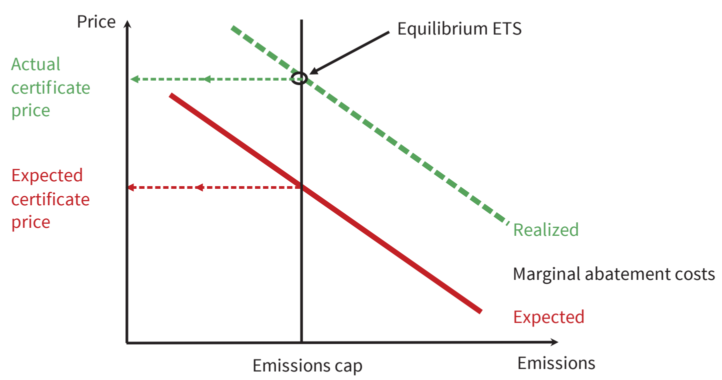
EMISSIONS TRADING

In an emissions trading scheme, also known as "cap and trade", the regulator issues a limited quantity of emission certificates. Companies subject to the scheme must hold such a certificate for emitting one tonne of CO_2 and submit it by the end of the year. The total quantity of certificates – also known as the cap – determines the total emissions within a year. Certificates are distributed either by auction or free of charge on the basis of historically determined benchmarks ("grandfathering"). Companies can trade certificates among themselves; the market price is formed by supply and demand. How many certificates a company wants to buy or sell depends on its marginal abatement costs. If these costs are below the market price for some of its emissions, it is worth saving these emissions and selling surplus certificates at the market price.

Uncertainty about abatement costs implies uncertainty about the demand for emission certificates. In emissions trading, the supply of certificates is fixed. Thus, supply and demand can clear only through a price adjustment (see Figure 2).

If the abatement costs are higher than expected, this can lead to a considerable increase in the certificate price and impose a higher burden on companies and consumers. Conversely, a lower demand for certificates reflects in a lower market price. If companies and households expect that the certificate price will be low in the medium and long term, this may lead to less investment in new technologies and to higher abatement costs in the future. In addition, an emission cap renders additional policy futile. For example, a replacement premium for oil-fired heating systems will no longer have a direct climate impact. They merely cause emissions to occur elsewhere or at a different time as the quantity of allowances remains constant. The same applies to voluntary energy saving by private households (Perino 2015). In summary, pure quantity regulation guarantees compliance with given reduction targets, but can lead to considerable price fluctuations. Consequently, it limits planning secu-

Figure 2
Functionality of Emissions Trading Scheme (ETS)



Source: Authors' illustration.

rity for companies and consumers (BMWi 2019) and renders additional measures ineffective.

HYBRID PRICING APPROACHES

The government's decision, at least for 2026, does not stipulate a "pure" emissions trading system, but a so-called "hybrid" system of price and quantity control. Traditional emissions trading is supplemented by a lower and/or upper limit for the market price.[6] The intention is to reduce the extent of possible price fluctuations in an emissions trading system and thus provide greater planning security. If both a minimum and a maximum price are introduced, this is referred to as a "price corridor" (see Figure 3). Such a corridor is stipulated for national emissions trading in Germany starting in 2026, whereby the minimum price will be EUR 55 and the maximum price EUR 65/tCO_2. In 2025, it will be decided whether such a price corridor will be maintained after 2026 or whether the system will be converted into a classic emissions trading scheme. A minimum price in an emissions trading system can be implemented in various ways (Edenhofer et al. 2019):

- Reservation price at auctions of certificates: certificates will be retained as soon as the bids are below the minimum price.
- Purchase of already circulating certificates on the secondary market.
- Introduction of a CO_2 price support (carbon price support): this is an adaptive tax that compensates for the difference between the targeted minimum price and the current market price. Such an instrument exists in the United Kingdom in the electricity sector.

[6] See, among others, Roberts and Spence (1976), Pizer (2002), Wood and Jotzo (2011) as well as BMWi (2019), Edenhofer et al. (2019) and SVR (2019) in the context of the German debate.

How a minimum price is to be implemented in the German emissions trading system is still unclear. In order to implement a maximum price, additional certificates must be issued on the market when this price level is reached (BMWi 2019). Similar to a price regulation, an emissions trading system with an upper price limit does not guarantee compliance with quantity targets. Given the high degree of uncertainty about the abatement costs in the non-ETS sectors in Germany, such a price ceiling can be reasonable (SVR 2019). If prices fall again below the maximum price after the additional certificates have been issued, a decision must be made as to whether and how the additional certificates will be withdrawn from the market. The corresponding course of action in the German system remains unclear.

THE FLEXCAP: A BETTER WAY OF DEALING WITH UNCERTAINTY

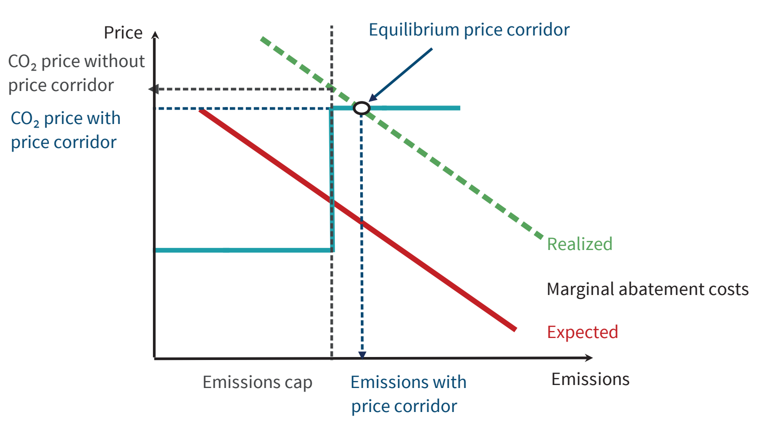
The simple emissions trading scheme passes all uncertainty to companies and consumers in the form of price fluctuations. A tax shifts all uncertainty onto the emission quantity and puts reduction targets in jeopardy. A price corridor passes the uncertainty to companies and consumers as long as the price fluctuations remain within the corridor, and to the emission quantity otherwise. The most efficient way, however, is to divide uncertainty continuously between price and quantity. Karp and Traeger (2020) propose an intelligent emissions trading scheme for this purpose, the so-called "smart cap".[7] We present here a somewhat simplified version as the Flexcap and adapt it to the German debate and objective. As stressed before, it could also be an alternative for a reform of the EU ETS or other (inter-)national ETS.

Mechanism and Mode of Action

When implementing a Flexcap, the price and quantity are determined along a special supply curve for certificates. This so-called "adjustment function" determines the quantity of allowances to be auctioned as a function

Figure 3

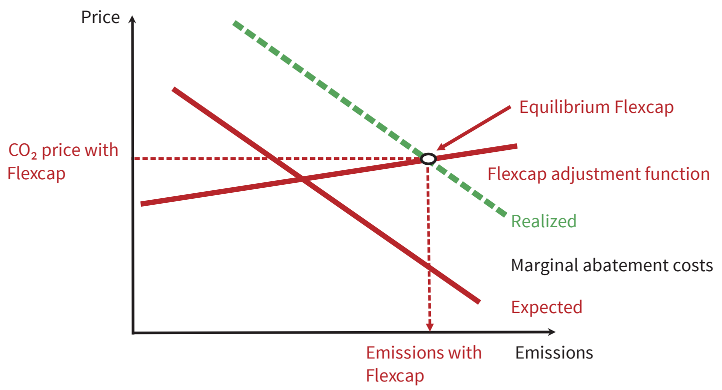
Price Corridor (Upper and Lower Price Limit)



Source: Authors' illustration. © ifo Institute

[7] Certificates whose CO_2 equivalent is a function of the market price are traded in the "smart cap". In this way, certificates that have already been issued are adjusted to the market price in real time. In the applied version, certificates continue to be issued in tonnes of CO_2, and the auctioned quantity of certificates adjusts to the market price with a slight delay. Unold and Requate (2001) have already proposed the implementation of a related system by issuing options. Perino and Willner (2017) also argue for a certificate supply function with a positive slope. Also, Rickels et al. (2019) discuss proposals on CO_2 pricing and note the advantages of a flexible certificate supply.

Figure 4
Flexcap



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of the price (see Figure 4). If the price is high, more allowances are auctioned and the cap expands. If the price is low, fewer certificates are auctioned and the cap decreases. Both adjustments stabilize the price compared to an emissions trading system with a fixed cap. The slope of the adjustment function determines how much emphasis is placed on price stabilization (more emphasis the flatter the slope) and how much emphasis is placed on the quantity target (more emphasis the steeper the slope). A CO_2 tax and emissions trading with a fixed cap are extreme variants of this mechanism.

There are various possibilities for the practical implementation of this quantity adjustment. We propose a very simple version: the new amount of certificates to be auctioned should depend directly on the price of the previous auction.[8] In the EU ETS, auctions usually take place on a weekly basis. In a smaller German system, auctions are expected to take place only every two or four weeks.[9] For example, a high price in May would lead to more certificates being auctioned in June. Since certificates have to be submitted only at the end of the year and the adjustment function is known to all market participants, the adjustment in June is already anticipated at the auction in May, which dampens the price increase without delay. If, on the other hand, the price is very low in May, the amount of certificates auctioned in June will be reduced according to the adjustment function.

Table 1 contains a comparative example of the effect of the Flexcap and the classical systems discussed previously. Our example contains both a flat and a steep choice of the adjustment function. We will return to the choice of this slope in the next section.

The example refers to the EU ETS in 2020. We assume that the adjustment function is given, the expected abatement costs are EUR 25/tCO_2 and the expected emission quantity is 1.60 GtCO_2.[10] However, the actual abatement costs are higher.[11] Under a price regulation, a CO_2 tax of EUR 25/tCO_2 would be introduced. The realized emissions would then be approx. 10 percent above the expected level.

In an emissions trading system, certificates with a total volume of 1.60 GtCO_2 are issued. With such a rigid emissions cap, the price of a certificate rises to over EUR 37/tCO_2, an increase of 50 percent above the expected price. The example illustrates how pure emissions trading passes all uncertainty to the certificate price and thus to companies and consumers.

[8] An average value of the prices of previous auctions could also be used to determine the new quantity to be auctioned. In this case, it makes most sense to weight the last auction most heavily in order to achieve the closest possible approximation. It is also conceivable to consider the stock market values of the secondary market. In an auction in which the companies specify demand functions as in the auctions of the EU ETS, the resulting auction price itself can also be taken into account.

[9] If there are about twelve auctions per year, then we suggest that each of these twelve auctions in a calendar year follows the same adjustment function, and thus one-twelfth of an annual adjustment function.

[10] The actual cap in the EU ETS for 2020 is approx. 1.81 GtCO_2 (see https://ec.europa.eu/clima/policies/ets/cap_de). However, the observed GHG emissions have been lower since 2016 (see https://www.eea.europa.eu/data-and-maps/dashboards/emissions-tradingviewer1). We therefore adjust the cap downward in the example. The price here roughly corresponds to the current market price (beginning of September 2019).

[11] The increase in the expected marginal abatement costs is based on the parameterization of Landis (2015; see Table 4). However, the position of the marginal abatement cost curve was adjusted upward for this example. Otherwise, the cap used would result in a certificate price of less than EUR 20/tCO_2, which seems too low given the pre-Corona market prices in the EU ETS. The actual abatement costs realized in the example were freely chosen as a possible scenario.

Table 1
Flexcap and Classic System: Comparison of Effects

	Expected price in euros	Realized price in euros	Expected amount in GtCO_2	Realized amount in GtCO_2
CO_2 tax EUR 25/tCO_2	25.00	25.00	1.60	1.75
Emissions trading with Cap 1.60 GtCO_2	25.00	37.19	1.60	1.60
Price corridor EUR 20–35/tCO_2	25.00	35.00	1.60	1.63
Flexcap with flat adjustment function	25.00	26.00	1.60	1.74
Flexcap with steep adjustment function	25.00	35.00	1.60	1.63

Source: Authors' calculations.

A tax, on the other hand, passes all uncertainty to the emissions and puts the quantity target in jeopardy.

The third row in Table 1 refers to a price corridor with a minimum price of EUR 20/tCO_2 and a maximum price of EUR 35/tCO_2. In this case, the price is stabilized at the price ceiling of EUR 35/tCO_2; the resulting emissions exceed the targeted emission ceiling.

Rows 4 and 5 illustrate the Flexcap. With a flat slope, it allows the price to rise only slightly, but allows a stronger expansion of the certificate quantity. With a steeper adjustment function, it allows a stronger price increase, but forces emissions that hardly deviate from the target quantity.

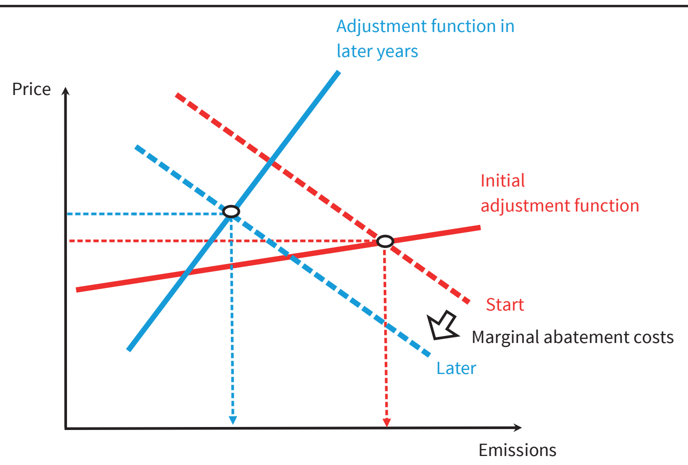
Choice of Adjustment Function and Efficient Achievement of Objectives

The economic literature largely agrees that uncertainty about marginal abatement costs leads to particularly high costs when fully passed on to consumers and businesses, as in a pure emissions trading scheme.[12] This uncertainty is particularly severe when a new emissions trading system is introduced, not least because it covers sectors that have not been exposed to a direct CO_2 price before. We therefore propose an initially relatively flat adjustment function. This flat adjustment function should, of course, go through the price/quantity combination targeted for the year in question. Similar to the German government's decision, households and companies can gradually get used to pricing emissions without being exposed to large price fluctuations. Very low prices, which reduce the incentives to invest in emission abatement technologies, would be avoided, as would very high prices, which put an excessive burden on households and companies, for example because they cannot react quickly enough to CO_2 prices, due to a lack of short-term available and affordable alternatives.

The initial costs for consumers and companies have to be weighed against the long-term achievement of climate targets. The adjustment function should therefore become steeper over time (see Figure 5). A steep adjustment function leaves less scope for extending (or reducing) the Flexcap in order to avoid excessively large deviations from the targets set for 2030 or 2050.[13] The gradual decline in flexibility in adjusting emissions gives households and companies time to get used to and deal with higher prices and price fluctuations.

The definition of the form of the adjustment function within each year and its evolution over time is ultimately a political decision. However, the decision-making process could be supported by economic simulation models. The adjustment function could be calculated both for a specific period and over time in a way that the overall costs of achieving the long-term emissions target would be as low as possible. In this way, the adjustment function would be determined according to the best knowledge about current and future abatement technologies and costs. It can also take into account the extent to which other countries implement a comparable CO_2 price in the relevant sectors. This is important if German companies are in competition with foreign ones. The more countries price CO_2, the less susceptible are companies based in Germany to these concerns about higher prices. If further relief is required for individual companies competing internationally, this could be implemented under the Flexcap in the same way as it is currently done in the EU ETS, with allowances allocated free of charge. In the transport and heating sector, however, the number of companies whose competitiveness is endangered by a CO_2 price may be much smaller than in the manufacturing sector, since mobility and heating are inherently site-specific services. The adjustment functions should already be set today for a foreseeable period, for example up to the target years 2030 or 2050. In this way, regulatory uncertainty can be significantly reduced.

Figure 5
Increase in Slope of the Flexcap



Source: Authors' illustration.

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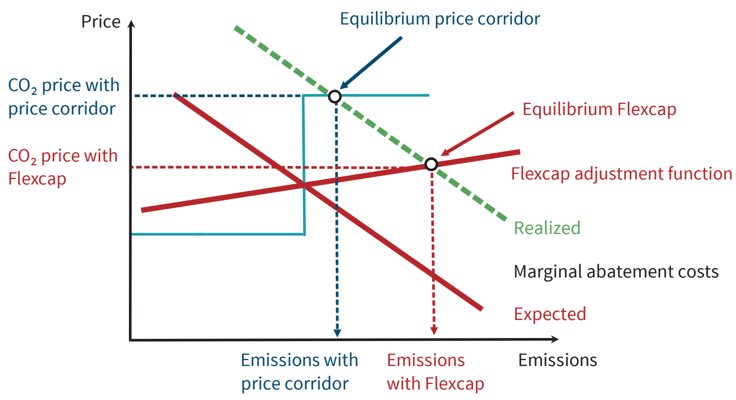
[12] See Newell and Pizer (2003) and Hoel and Karp (2002) for this result on CO_2 regulation. Karp and Traeger (2018) show that when technical progress is made, price stabilization should be somewhat less important than traditionally assumed, but even then, a full shift of uncertainty to consumers and companies is not efficient.

[13] For the year 2030 or 2050, the Flexcap should run through a point that combines the quantity target set by Germany with a price acceptable to society. The slope could be based on the compensation payments due if the quantity target is not reached. Of course, the adjustment function does not have to be linear or symmetrical around the target.

DISCUSSION

As outlined above, the Flexcap has clear advantages when dealing with uncertainty, compared to a CO_2 tax and a conventional emissions trading scheme. Among the proposals in the public discussion, emissions trading with a price corridor comes closest to the Flexcap. In comparison to a price corridor, a Flexcap reduces the price uncertainty for companies and consumers at all times, and thus irrespective of the level of price fluctuations (see Figure 6). The adjustment function automatically determines how many certificates are made available to the market. In this way, a surplus of certificates does not remain in the system after a short-term price increase, but is gradually withdrawn from the market by automatically auctioning fewer certificates in future auctions. In an emissions trading system with a price corridor, this is usually the case only if allowances are bought back by the state. The German government's decision leaves open whether this would be the case in the planned German emissions trading system.

Figure 6
Flexcap



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A Flexcap does not require active management and therefore incurs only low implementation cost. Since companies are aware of the current and future shape of the adjustment function, regulatory uncertainty is low. The danger that a Flexcap system develops in a way that is undesirable and thus creates political pressure for a change of rules is less than in case of a CO_2 tax or an emissions trading scheme with a fixed cap. The tax has to be readjusted if the climate targets are missed by too much, and a simple emissions trading system runs the risk that prices will not meet expectations. For this reason, significant corrections have been made to the EU ETS several times in recent years. The Flexcap draws on these experiences and reduces the risk of subsequent adjustments to the rules, thus increasing planning security for companies. Consequently, such a flexible system means a clear location advantage over countries with a pure CO_2 tax system or a pure emissions trading system.

We refer to Karp and Traeger (2020) for the discussion of the effects and neutralization of potential market power in Flexcap as well as the discussion of "banking," i.e., the storage of certificates. A German Flexcap for the non-ETS sectors would already include a sufficient number of market participants, so market power should not be expected. Since the adjustment function dampens the extent of uncertainty, for example from economic fluctuations, this takes care of a key argument for the transferability of certificates to future years (banking). For this reason, our proposal is to issue certificates valid for a specific calendar year and not to allow banking.[14] The German government's decision does not address the question of whether certificates can be transferred to future years.

Compared to this system to be implemented, the Flexcap would offer a more efficient solution that simultaneously tracks price and quantity targets and could avoid the already planned system changes and readjustments. It remains to be seen in which system and at what price the federal government will achieve its 2030 quantity target. This creates uncertainty for planning which, combined with low initial prices, can have a negative impact on investment and innovation. With the introduction of the Flexcap, Germany could establish itself as an innovative model for a better system of emission pricing, and thus for a more cost-effective achievement of long-term climate policy goals.

For an expansion at the EU level, it is important to note that the Flexcap is not a tax. Therefore, it would not fall under the unanimity requirement of the Lisbon Treaty. Even in Germany, the legal basis for the introduction of a de facto tax, as planned for the years 2021–2025, has not yet been definitively clarified.[15] Should the Flexcap be applied at the EU level in the medium term, the implementation hurdles would correspond to those of a modification to

[14] In emissions trading with a fixed cap, banking means that the expected price development over the entire banking horizon is based on the market interest rate (Silbye and Sørensen 2019). This is generally not optimal and can lead to considerable regulatory uncertainty if the details of subsequent phases are not known.

[15] Germany's Basic Law does not provide for direct taxation of CO_2 emissions (Article 106 GG). An emissions trading scheme that limits the quantity of allowances and thus forms the price on the market has already been classified as constitutional (e.g., 1 BvR 2864/13). However, this is not the case in the federal government's 2021–2025 proposal (and, strictly speaking, not in the subsequent emissions trading with price corridors). In our Flexcap proposal, the price of the previous period fixes the quantity of allowances to be auctioned and the price forms on the market.

the existing emissions trading system. It would be considerably more transparent and effective than the market stability reserve (Perino 2018), whose first review is scheduled for 2021, with others to follow every five years. If the currently planned German system does not pass potential judicial contests, the introduction of a Flexcap in Germany and its subsequent transfer to EU emission trading would be a realistic option.

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*Maria Hofbauer Pérez and Carla Rhode**

Carbon Pricing: International Comparison

Until the outbreak of the coronavirus pandemic, global warming was the most critical challenge that the world is facing. The crucial drivers of climatic change and particularly global warming are increasing greenhouse gas emissions, especially CO_2. As the Global Warming Index published by Oxford University Environmental Change Institute shows, global warming has been primarily induced by human activities since approximately 1885 and this human-induced influence has increased dramatically since 1960. Hence, the rise in temperature is approaching critical levels, with an increase of the global average temperature by 1.1°C compared to the pre-industrial period and by 0.2°C referring to global average temperatures in 2011–2015 (World Meteorological Organization 2019). It is the central aim of the Paris Agreement to keep the global temperature rise this century well below 2°C (see Figure 1). As a result of rising global temperatures, far-reaching and drastic consequences like extreme weather conditions, melting of the Arctic sea ice and a rise in sea levels are globally observable and call for urgent action. In recent years, the societal pressures for effective political action have also increased significantly. Consequently, actions against global warming are becoming increasingly important and are playing a central role in the political agenda of nations and global organizations.

At the EU level, a trading system was introduced by the European Commission in 2005, as the cornerstone of the EU's policy to combat climate change. More specifically, the European Emissions Trading system (ETS) was set up as a carbon market with a cap-and-trade system that is set out to continuously reduce emission allowances. It is one of the largest and longest operating trading systems of the world and serves as a role model for other trading systems (Borghesi, Montini, and Barreca 2016). The EU ETS currently covers 45 percent of European Greenhouse gas emissions (European Commission 2019). However, apart from covering only European emissions, this trading system is criticized for not reducing emissions to a sufficient extent to slow down global warming (Schmitt 2017). Furthermore, on a global level, the Paris Agreement entered into force in 2016 after negotiations between 195 countries. The signatory states commit themselves to implementing effective policies to limit global warming to 2°C and to pursue efforts to limit temperature rise to 1.5°C.[1] Under this agreement, nations must submit national climate action plans containing their measures against climate warming. A crucial part of these actions are carbon pricing approaches using either trading or taxation systems to reduce emissions.

The following article gives a basic overview of carbon pricing combined with current data about carbon emissions and international carbon pricing. It sheds light on the basic concepts of carbon pricing approaches referring to taxation and cap-and-trade schemes. First, a general overview of the mechanisms behind the two different approaches is given. Second, emissions are compared internationally and over time. Moreover, the most important fuel types and sectors for carbon emissions are described. Third, the coverage of emissions by pricing schemes is considered. The main part compares pricing schemes in more detail across countries focusing on the time of introduction and basic characteristics, the coverage of emissions, the price for emitting, and resulting revenue as well as exemptions.

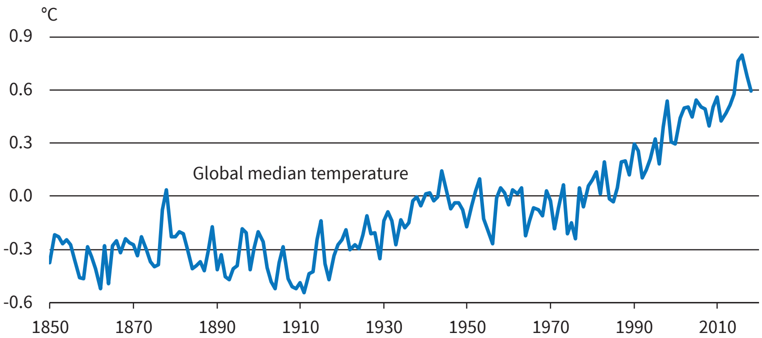
POLICY APPROACHES: TAXATION AND CAP-AND-TRADE SYSTEMS

Greenhouse gas emissions induce negative externalities via global warming. For emitters, to account for these negative externalities in their individual decisions (internalization), policy interventions are required. From an economic perspective, there are two mechanisms for the reduction of greenhouse gas emissions. The first one refers to taxation of emitted greenhouse gases, the second one to a cap-and-trade system of greenhouse gas emission certificates. Both systems implement the internalization by setting a price on emissions but differ in their approaches:

Figure 1

Development of Temperature Anomalities over Time

Relative to 1961–1990 average global temperature



Source: Our World in Data (2019); Hadley Centre. © ifo Institute

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[1] Both Celsius goals are measured in respect to pre-industrial temperature levels.

taxation schemes pertain to price regulation approaches, whereas cap-and-trade schemes are categorized as quantity regulation systems. The following section describes the principal mechanisms, highlighting key advantages and disadvantages of both.

The main idea behind taxation schemes is to incentivize emitters to invest in more sustainable technologies. However, it requires that the expenditures needed to reduce emissions by a specific amount (also known as the abatement costs) are lower than the tax burden accumulating from this amount of emissions. As the abatement costs are hard to quantify, setting the right carbon tax is challenging. For example, if the abatement costs are higher than the tax burden, reductions in emissions can be far below the target.

Cap-and-trade systems, on the other hand, consist of a limited number of emission certificates that authorize owners to emit a certain amount of CO_2 and which can be traded within the system. Consequently, emission reduction targets are the principal starting point, as they form the basis for setting the number of certificates. At the beginning, the total number of certificates are delivered by the state via auctions or free allocations. Afterwards, trading is induced by supply and demand, which determines the price of the certificate. Emitters are incentivized to trade their permits, if the price they receive from selling a certificate is higher than the abatement costs. Thus, emitters make a profit by selling the certificate to another emitter whose abatement costs lie above the price of the certificate. As the abatement costs are also uncertain when using a cap-and-trade system, a sharp increase in the price of certificates is possible whenever abatement costs and hence the demand for emission certificates are high. This could lead to a disproportionately higher burden for emitters (Traeger et al. 2019).

CO_2 EMISSIONS WORLDWIDE

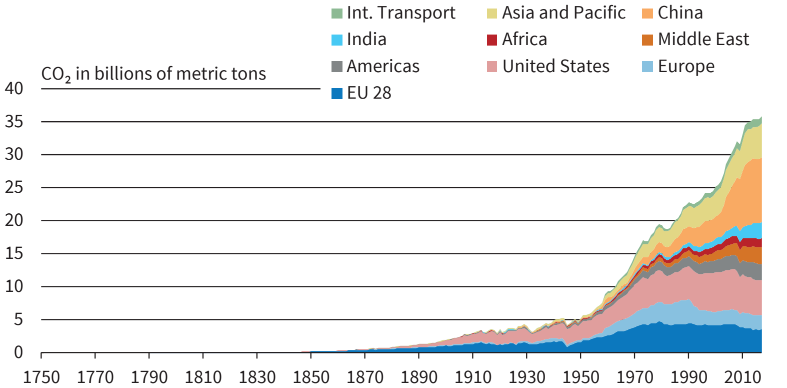
Globally, CO_2 emissions have reached their highest level with 36 billion metric tons being emitted in 2017. Emissions have followed an increasing trend for the last 250 years (see Figure 2), with annual growth rates averaging around 3 percent. The sharpest increases occurred with the beginning of industrialization in 1830 with an average rate of 5 percent in the period up until the beginning of World War I. Currently, China and the United States emit the largest quantity of CO_2, as seen in Figure 2[2], followed by India and Russia. China and the US make up 42 percent of global emissions. Including India and Russia, the emissions of top emitters amount to more than half of global emissions (53 percent).

The emissions of China and India in particular have grown in recent years, as opposed to the total emissions of Europe staying relatively constant or even decreasing in the last few decades. In the United States, emissions have remained relatively constant since 1983, with a slight decline in emissions in recent years. While in 1900, the EU28 countries emitted 56 percent of total global emissions, this share dropped to 10 percent in 2017. China and India on the other hand merely emitted 0 percent[3] and 1 percent, respectively, in comparison to total global emissions in 1900. Nowadays, China's contribution to total emissions amounts to 27 percent, while India emits 7 percent of global emissions. The share of emissions produced in the United States and in European countries over time are comparable. In 1990, the US emitted 34 percent of total global emissions, whereas in 2017 the share amounted to 15 percent. The cumulative share of emissions by region further reflects these relative developments (see Figure 3). Here, the crucial finding is that Europe and the United States have contributed most to total global emissions over time.

In addition to total emissions, statistics also capture emissions per capita. Figures 4 and 6 illustrate this difference, with Figure 4 showing emissions by country and Figure 5 showing the per capita emissions. It becomes evident that the largest emitters in absolute terms are in fact not the largest emitters per capita. While China and the United States emit the greatest amount in total, Qatar ranks first in terms of per capita CO_2 emissions with 49 metric tons

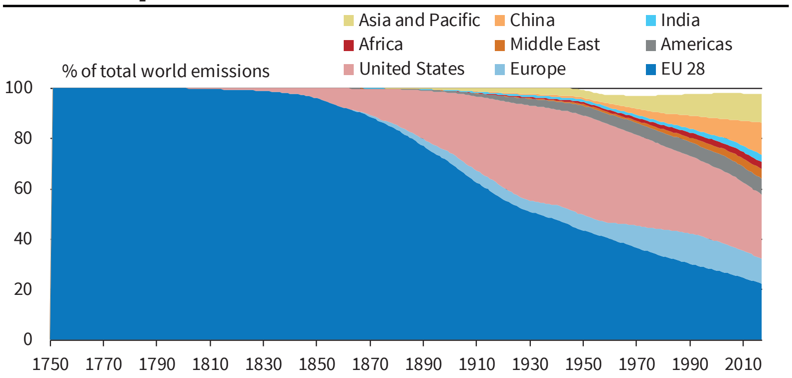
[2] International transport (international aviation and shipping), which became relevant in the middle of the 20th century, is excluded as it is not assigned to specific world regions. Hence, the cumulative emissions relative to total world emissions of the last few decades do not add up to 100 percent.
[3] For China, no data is available for 1900, so we use the next available year, which is 1902.

Figure 2
Annual World's CO_2 Emissions by Region, 1751–2017



Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

Figure 3
Cumulative CO_2 Emissions over Time



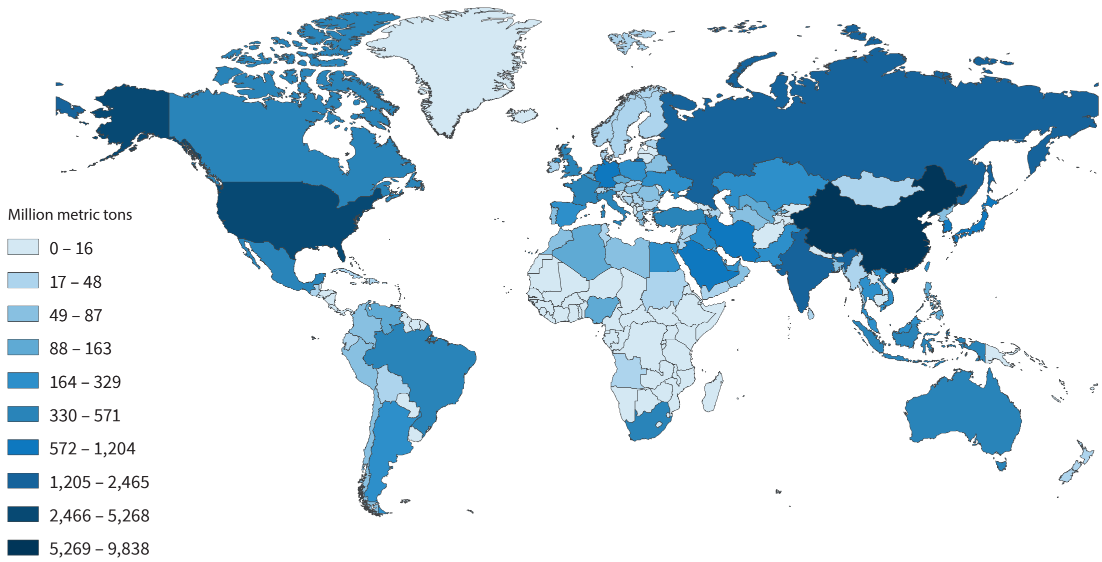
Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

per capita annually, followed by Trinidad and Tobago with 30 metric tons per capita and Kuwait with 25 metric tons per capita. The United States is ranked 9th with 16 metric tons per capita while China is ranked 41st with 7 metric tons of CO_2 per capita.

EMISSIONS BY FUEL TYPE AND SECTOR

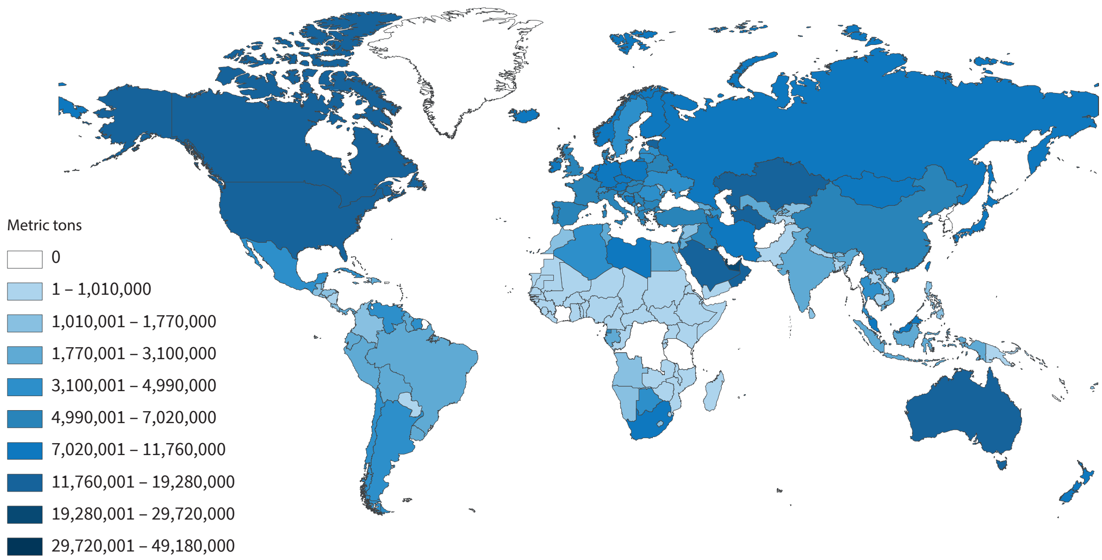
Emissions are primarily caused by fossil fuels used in

Figure 4
CO_2 Emissions by Country



Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute

Figure 5
CO_2 Emissions per Capita by Country

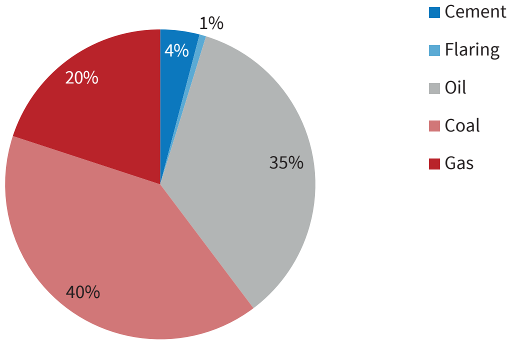


Source: Our World in Data (2019); Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC). © ifo Institute different sectors. Overall in 2017, the world's emissions were associated with five different fuel types (see Figure 6). Coal accounts for the largest share of global emissions (40 percent) followed by oil (35 percent) and gas (20 percent). The remaining 5 percent are associated with the production of cement (4 percent) and flaring (1 percent). The predominant sectors causing emissions are the electricity and heat production sectors, which accounted for 49 percent of total global emissions in 2014 (see Figure 7). Second place was shared by the manufacturing and construction industries and the transportation sector, each accounting for 20 percent of total emissions in 2014. The share of residential buildings and commercial and public services amounts to 9 percent of total global emissions. The remainder of 2 percent is spread across other sectors.

INTERNATIONAL COMPARISON OF CARBON PRICING SCHEMES

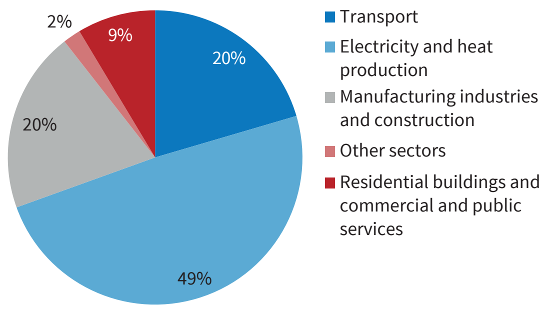
Various carbon pricing schemes have already been introduced at the sub-national, national, and regional level to combat rising greenhouse gas emissions. In addition, several policies are under consideration or already scheduled for implementation. The following section will compare existing international carbon pricing schemes, looking closer at the time of introduction, their coverage, the prices for emissions and resulting revenue, as well as at their effectiveness in reducing emissions.

Figure 6
Emissions by Fuel Type in 2017



Source: Our LZ World in Data (2019); Global Carbon Project (GCP); Carbon Dioxide Information Analysis Center (CDIAC). © ifo Institute

Figure 7
World Emissions[a] by Sector in 2014



[a] CO_2 emissions from transport do not contain emissions for international marine bunkers and international aviation (domestic aviation, domestic navigation, road, rail and pipeline transport).

Source: Our LZ World in Data (2019); Global Carbon Project (GCP); International Energy Agency (IEA) via The World Bank. © ifo Institute

Time of Introduction

In 2019, there were 56 carbon pricing instruments implemented including all carbon tax as well as ETS initiatives on national, regional, and sub-national level. While there were 27 ETS systems, the number of carbon taxation schemes amounted to 29.

Almost one-third of the carbon tax systems were introduced in the 1990s, by Scandinavian countries (Finland in 1990, Norway and Sweden in 1991, and Denmark in 1992) as well as Poland and Slovenia (see Table 1). Most of the carbon taxation schemes were implemented only after 2000. Smaller countries, including Estonia, Latvia, Liechtenstein, Switzerland, Iceland, and Ireland followed by 2010 and Japan followed in 2012 as the first non-European country. More than one-third of the carbon tax policies were introduced in the last five years alone, with national taxation schemes implemented in Canada, Singapore, and South Africa. In Côte d'Ivoire and the Netherlands, taxation systems are scheduled for 2020, and in Senegal taxation schemes are under consideration. Table 1 summarizes the years of introduction for all taxation systems and lists a general description of the specific schemes indicating the differences and variety of structures.

The first trading systems were introduced in 2005, and thus at a much later stage than the taxation systems (see Table 1). While most taxation systems are at the national level (World Bank 2019), the first trading system was introduced at the supranational EU level in 2005. The larger nations of Australia and Canada followed suit in 2016 and 2019, respectively. It is interesting to note that most countries with an ETS system do not implement an additional carbon taxation scheme. However, Switzerland and Canada use both carbon pricing systems (trading and taxation). Moreover, five of the eight countries that already apply a carbon tax system currently have an ETS scheduled or under consideration. For 2020, China has scheduled an emission trading system that is expected to have a large impact on emission coverage, as China is globally one of the largest emitters of greenhouse gases. Many other countries like Chile, Japan, and Turkey are considering trading schemes for CO_2 emission reduction (Table 1).

Emissions Coverage

While introducing carbon pricing policies worldwide is a crucial step toward mitigating climate change, it is important to consider the share of emissions that such policies cover. Overall, both the number of carbon pricing initiatives as well as the share of annual global greenhouse gases covered has increased substantially in the past 20 years. In 2005, the number of implemented policies jumped from 8 to 9 with the introduction of the EU ETS, which led to an increase in covered emissions from 0.25 percent to 3.7 percent globally. A similar jump can be observed in 2012, with the introduction of the carbon tax scheme in Japan, resulting in a total of 24 implemented initiatives and a jump in covered emissions from 4.9 percent to 7 percent.

Looking closer at the emissions coverage, all implemented initiatives covered 14.9 percent of global greenhouse gas emissions in 2019. The EU ETS system accounts for the greatest share of approximately 3.9 percent, followed by Japan's carbon tax (1.8 percent) and Korea's ETS

Table 1

Regional and ational Carbon Pricing Schemes Implemented and under Consideration[1]

Country	Year of implementation	Short description
Finland, carbon tax	1990	Component of energy tax, covers life-cycle emissions of fuels for heating and work machines.
Poland, carbon tax	1990	Tax on several emissions, like dust, sewage, and waste.
Norway, carbon tax	1991	Consisting of an excise tax on mineral products and a specific law for petroleum activities on the continental shelf.
Sweden, carbon tax	1991	Component of energy tax for carbon-intensive fuels.
Denmark, carbon tax	1992	Tax on all fossil fuels applying to GHG emissions from mainly the building and transport sectors.
Slovenia, carbon tax	1996	Tax on natural gas and all liquid and solid fossil fuels.
Estonia, carbon tax	2000	Taxes covering all fossil fuels applying to industry and power sectors generating thermal energy.
Latvia, carbon tax	2004	Tax covering fossil fuels from industry and power sectors not covered under the EU ETS.
EU, ETS	2005	Cap-and-trade system with four phases including annual cap reductions and regular updates of exemptions and allowances. It targets CO_2 emissions from the industry, power, and aviation sectors, including industrial processes as well as N_2O from certain chemical sectors and PFC from aluminum production
Liechtenstein, carbon tax	2008	Tax on CO_2 emissions from the industry, power, building, and transport sectors.
Switzerland, carbon tax	2008	Complementary to Swiss ETS on all fossil fuels.
New Zealand, ETS	2008	Trading scheme where government distributes emission certificates to foresters to sell them on the market. Units bought by emitters must be again handed in to the government.[2] It targets GHG emissions from industry, power, waste, transport, and forestry sectors as well as emissions from industrial processes.
Switzerland, ETS	2008	Mandatory cap-and-trade system for large energy-intensive industries (voluntary for medium-sized industries) linked to the EU ETS. It applies to the industry and power sectors as well as industrial processes.
Iceland, carbon tax	2010	Part of Environmental and Resource tax covering liquid and gaseous fossil fuels from all sectors, with exemptions.
Ireland, carbon tax	2010	Tax covering all fossil fuels from all sectors, with exemptions.
Ukraine, carbon tax	2011	Tax covering all fossil fuels from stationary sources.
Japan, carbon tax	2012	Tax covering all fossil fuels for all sectors, with exemptions.
UK, carbon price floor	2013	Tax on CO_2 emissions from power sector, with exemptions.
Kazakhstan, ETS	2013; suspended in 2016–2017; reintroduced 2018	Cap-and-trade system for emissions of large emitters with free allowances based on historical emissions or product-based benchmarks.
France, carbon tax	2014	Part of tariffs on consumption of energy covering all fossil fuels from all sectors, with exemptions.
Mexico, carbon tax	2014	Excise tax on production and services targeting additional CO_2 emission content compared to natural gas.
Spain, carbon tax	2014	Tax on fluorinated greenhouse gases from all sectors, with exemptions.
Portugal, carbon tax	2015	Excise tax on consumption covering all fossil fuels applying to mainly the industry, building, and transport sectors.

[1] This table focuses on national carbon taxes and on regional and national carbon trading schemes. However, there exist sub-national initiatives of carbon taxation schemes as well as sub-national trading initiatives. For example, the regional government of British Columbia in Canada introduced a carbon tax in 2008, hence long before the federal state implemented a federal scheme. Moreover, the province of Alberta in Canada introduced an ETS system in 2007.

[2] https://www.mfe.govt.nz/climate-change/new-zealand-emissions-trading-scheme/about-nz-ets.

Korea, ETS	2015	Cap-and-trade system with benchmark-based allocation of certificates and auctioning, regulations are changed/updated with the start of a new phase of the system. It targets GHG emissions from the industry, power, building, domestic aviation, public, and waste sectors.
Australia, ERF Safeguard Mechanism	2016	Baseline-and-offset system for large emitters incentivizing emissions to be held below specific baselines, which are regularly updated. Above the baseline, Carbon Credit Units must be purchased. The system targets direct emissions including emissions from energy production.[3] It targets emissions from the industry and the power sectors including industrial processes.
Chile, carbon tax	2017	Part of the tax on air emissions from contaminating compounds covering all fossil fuels mainly taxing the power and industry sectors.
Colombia, carbon tax	2017	Tax covering all liquid and gaseous fossil fuels used for combustion targeting all sectors.
Argentina, carbon tax	2018	(Annually increasing) tax covering almost all liquid fuels and coal targeting all sectors, with exemptions.
Canada, federal fuel charge	2019	Legal requirement for all provinces and territories to implement a carbon pricing initiative aligned with federal standards; consists of a regulatory charge on fuels (tax-like component) and a baseline-and-credit ETS for emission-intensive and trade-exposed industrial facilities; applies to GHG emissions from all sectors, with exemptions.
Singapore, carbon tax	2019	Tax targeting GHG emissions from all fossil fuels used by facilities from the industry and the power sector with annual emissions of 25 ktCO_2e or more, exemptions apply to some sectors.
Canada, federal OBPS	2019	Approach for all provinces and territories without carbon pricing scheme or without system aligned with federal standards. It consists of tax-like component on fuels and a baseline-and-credit ETS (OBPS) for emission-intensive and trade-exposed facilities that emit more than 50ktCO_2e annually.
South Africa, carbon tax	2019	Tax on GHG emissions irrespective of the fossil fuel used from the industry, power, building, and transport sectors, with partial exemptions.
	Scheduled and under consideration	
China, ETS	2020	Applies to emissions from the power sector including CHP and power plant from other sectors. Other sectors will be included gradually during the three scheduled phases.
Côte d'Ivoire, carbon tax	2020	Tbd
Netherlands, carbon tax	2020	Carbon floor price for the electricity sector and carbon tax for industry.
Senegal, carbon tax	Tbd	Tbd
Chile, ETS	Tbd	Tbd
Colombia, ETS	Tbd	Tbd
Indonesia, ETS	Tbd	Tbd
Japan, ETS	Tbd	Tbd
Mexico, ETS	Tbd	Tbd
Turkey, ETS	Tbd	Tbd
Ukraine, ETS	Tbd	Tbd
Vietnam, ETS	Tbd	Tbd

[3] https://www.environment.gov.au/climate-change/government/emissions-reduction-fund/publications/factsheet-erf-safeguard-mechanism.

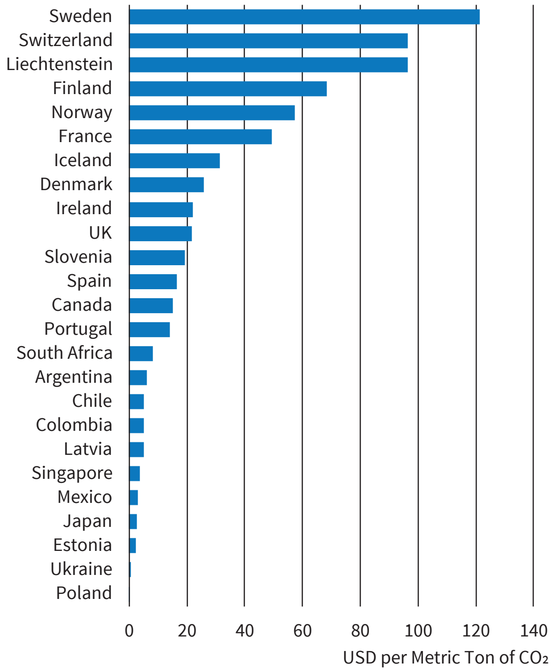
Source: World Bank (2019).

(0.9 percent). Figure 8 displays the share of the total global emission coverage that each individual carbon pricing scheme contributes to. In 2020, a substantial increase in the coverage of emissions is expected due to the introduction of the Chinese ETS system, which is expected to make up more than 25 percent of the future total covered emissions (see Figure 9) and will increase total coverage to 20 percent. The EU ETS had a comparable outreach when it was first introduced in 2005 (World Bank 2019).

Prices and Revenue

The price plays a central role in the taxation systems as it determines the cutoff point at which an emitting firm would decide to adapt an emission-reducing innovation/technology instead of paying the charges for its current emissions. The prices per metric ton of CO_2 (excluding purely fiscal fuel taxes) range from under USD 1 in Poland and Ukraine to a maximum of USD 127 in Sweden (Fig-

Figure 8
Carbon Tax Prices in 2019



Source: World Bank (2019). © ifo Institute

ure 8[4]). The top five countries with the highest prices are Sweden, Liechtenstein, Switzerland, Finland, and Norway.

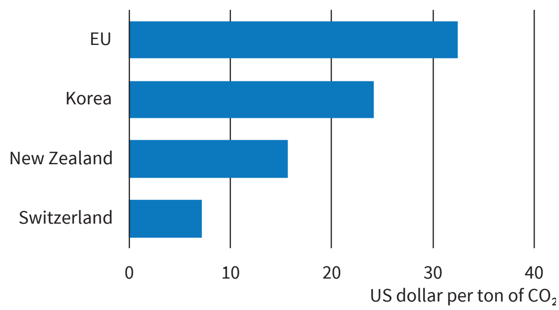
Figure 9[5] displays the ranking of the prices of trading systems. The European trading system has the highest price, amounting to USD 32 per metric ton of CO_2. With a price of USD 7 per metric ton of CO_2, Switzerland is in last place. In between is the Korean trading system (USD 24 per metric ton of CO_2) and the trading scheme of New Zealand (USD 16 per metric ton of CO_2).

Furthermore, the revenue raised also greatly differs between nations. Figure 10 compares the revenue raised in 2018. Excluding the ETS scheme of the EU with the largest amount of USD 15.948 million, the national carbon pricing schemes range from USD 0.4 million in New Zealand and USD 1 million in Poland to USD 8.1 billion in France (see Figure 10). Sweden raised the second-highest revenue (USD 2.5 billion), closely followed by Japan (USD 2.4 billion). However, both countries' revenue combined is still less than the revenue raised by France. When comparing the price and revenue structure, the rankings diverge. For example, while Japan is one of the five countries with the lowest carbon prices, it is the country with the third-highest revenue. Nonetheless, the Scandinavian countries that exhibit high price levels also accrue high revenue.

In general, when analyzing the revenue accrued from carbon pricing instruments, the question arises of how these public funds are used. In a cross-country study, Carl and Fedor (2016) find that 27 percent are used for investments in renewable energy and the increase of energy efficiency, 26 percent end up in public expenditures (not particularly linked to specific spending) and the largest part (36 percent) benefit taxpayers through tax cuts or direct discounts. When looking at the revenue from taxation schemes and emission trading systems separately, the authors find that, while revenue from emission trading systems is mostly reinvested into green technologies (70 percent), revenue from taxation schemes is mostly refunded to taxpayers and used for unspecified public expenditures (72 percent).

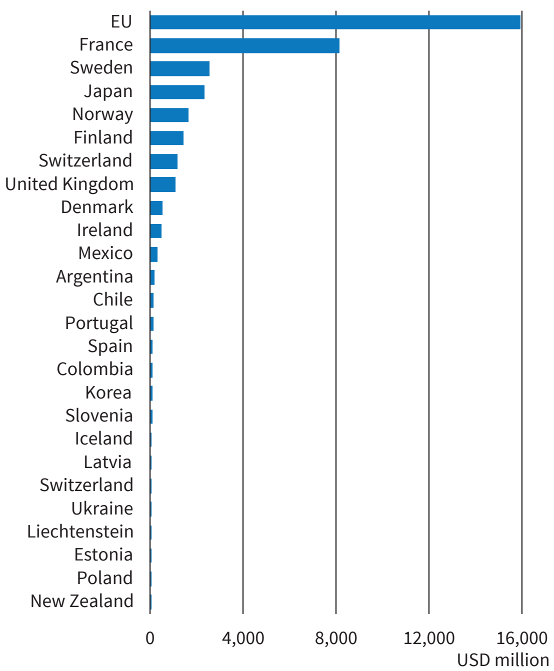
[4] This overview focuses on the principal price levels for fossil fuels for national carbon pricing schemes. Mexico, Argentina, Denmark, Norway, and Finland differentiate between two price levels for different fuel types. For more information, consult World Bank (2019).
[5] This overview focuses on national and regional ETS schemes. For Australia, Kazakhstan, and Canada, no prices are applicable. For more information, consult World Bank (2019).

Figure 9
Carbon Trade Prices 2019



Source: World Bank (2019). © ifo Institute

Figure 10
Revenues Raised from Carbon Pricing Schemes in 2018



Source: World Bank (2019). © ifo Institute

Exemptions

Most carbon price schemes have exemptions for specific sectors, fuel types, or energyintensive processes. National governments usually argue that exemptions are necessary in order to protect energy-intensive sectors and the international competitiveness of their national economy (World Bank 2019b). Table 2 gives an overview of (partial) exemptions in national and regional carbon pricing schemes. In general, emitters in European countries already covered by the EU ETS are (partly) exempted from national carbon pricing schemes. The most common exemptions refer to transportation and

Table 2
Exemptions of Carbon Pricing Schemes

Carbon Price Scheme	(Partly) Exemptions from carbon pricing	Others
Argentina carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☒ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Australia ERF Safeguard Mechanism	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Emitters up to their baseline emission level.
Canada federal fuel charge	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☒ Export of fuels ☐ Power/Heat	
Colombia carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Natural gas not used in the petrochemical and refinery sector.
Denmark carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
EU ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Finland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	Commercial yachting, coal and natural gas in industrial processes.
France carbon tax	☐Industry ☒ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	
Iceland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Ireland carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
Japan carbon tax	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Certain uses of fossil fuels in forestry.
Kazakhstan ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Free allowances for all emitters.
Korea ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Latvia carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Peat.
Liechtenstein	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Emitters with high carbon tax burden and competitiveness risks given that they reduce emissions by a specific amount by 2020, (partially) importers of transport fuels but with obligation to offset emissions.

Mexico carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Tax of maximum 3 percent of fuel sales price.
New Zealand ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of 60-90 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Norway carbon tax	☐Industry ☐ Transport ☒ Int. Aviation ☒Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☐ Power/Heat	Biofuels in mineral oil.
Poland		Operators with annual tax amount due less than 800 zloty.
Portugal carbon tax	☒Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	
Slovenia carbon tax	☒Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	
South Africa carbon tax	☐Industry ☒ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Exemptions from 60-95 percent for many sectors.
Spain carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Partially the use of fluorinated GHGs in certain sectors.
Sweden carbon tax	☐Industry ☒ Transport ☒ Int. Aviation ☐Int. Shipping ☒Agriculture ☐ Chemical processes ☒ Export of fuels ☒ Power/Heat	Forestry
Switzerland ETS	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☐ Power/Heat	Allowances of up to 100 percent of benchmark level for emission-intensive/trade-intensive sectors at risk of carbon leakage.
Switzerland carbon tax	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	Operators with high carbon tax burden and competitiveness risks given that they reduce emissions by a specific amount by 2020, partially importers of transport fuels but with obligation to offset emissions.
UK carbon price floor	☐Industry ☐ Transport ☐ Int. Aviation ☐Int. Shipping ☐Agriculture ☐ Chemical processes ☐ Export of fuels ☒ Power/Heat	

Source: World Bank (2019).

heat production. However, these sectors account for a large proportion of emissions (see Figure 7). Hence, against the background of climate targets, criticisms have arisen with respect to such exemptions (see for example Lin and Li 2011; Kemfert et al. 2019).

CONCLUSION AND DISCUSSION

This article describes carbon pricing approaches and their implementation in an international comparison. As shown, nations differ not only as to their carbon emission levels in various dimensions (over time, cumulative, per capita, etc.) but also as to their choice of carbon pricing methods. Most of them can be assigned clearly to one of the approaches. However, pricing schemes combining elements from both concepts are subject to the current scientific discussion. For example, emission trading initiatives with a price floor or ceiling unify trading and taxation elements by setting a maximum and a minimum price for carbon within an emissions trading system.[6]

Other suggestions follow a consumption-based approach, as for example carbon border taxes (also known as carbon tariffs). This approach is designed to address concerns about carbon leakage (firms producing in countries with less strict carbon pricing policies) and the resulting competitive disadvantages for countries due to carbon pricing. Broadly speaking, products from countries with less strict carbon pricing policies are subject to an import tax when they are imported into countries with stricter legislation (Rocchi et al. 2018). And still other

[6] A detailed mixed approach has been developed by the ifo Center for Energy, Climate, and Resources named “Flexcap.” For more detail see for example Traeger et al. (2019).

approaches argue in favor of command and control mechanisms setting binding limits to carbon emissions (Aldy and Stavins 2012).

In sum, research has shown that implementing different instruments of carbon pricing simultaneously can be inefficient (OECD 2011). However, well-designed carbon pricing schemes that combine the advantages of both approaches might be helpful in reducing greenhouse gas emissions effectively as well as efficiently and hence reduce global warming. Therefore, the design of carbon tax schemes as well as their exemptions should be continuously under consideration and open for adjustments in order to prevent global warming from exceeding important temperature limits.

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