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Advanced Review

Carbon pricing in climate policy: seven reasons, complementary instruments, and political economy considerations

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Carbon pricing is a recurrent theme in debates on climate policy. Discarded at the 2009 COP in Copenhagen, it remained part of deliberations for a climate agreement in subsequent years. As there is still much misunderstanding about the many reasons to implement a global carbon price, ideological resistance against it prospers. Here, we present the main arguments for carbon pricing, to stimulate a fair and well-informed discussion about it. These include considerations that have received little attention so far. We stress that a main reason to use carbon pricing is environmental effectiveness at a relatively low cost, which in turn contributes to enhance social and political acceptability of climate policy. This includes the property that corrected prices stimulate rapid environmental innovations. These arguments are underappreciated in the public debate, where pricing is frequently downplayed and the erroneous view that innovation policies are sufficient is widespread. Carbon pricing and technology policies are, though, largely complementary and thus are both needed for effective climate policy. We also comment on the complementarity of other instruments to carbon pricing. We further discuss distributional consequences of carbon pricing and present suggestions on how to address these. Other political economy issues that receive attention are lobbying, co-benefits, international policy coordination, motivational crowding in/out, and long-term commitment. The overview ends with reflections on implementing a global carbon price, whether through a carbon tax or emissions trading. The discussion goes beyond traditional arguments from environmental economics by including relevant insights from energy research and innovation studies as well. © 2017 The Authors. *WIREs Climate Change* published by Wiley Periodicals, Inc.

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INTRODUCTION

In the aftermath of COP21 in Paris, countries will have to turn pledges into effective policies, to guarantee that their promises about reduction of greenhouse gas (GHG) emissions are actually achieved. It is easy to underestimate this challenge. We will argue that to achieve the Paris targets, the use of the instrument of carbon pricing is essential, even though not sufficient. All alternative options are likely to lead to inadequate and overly costly abatement activities. Imprudent policy design could have extremely far reaching consequences, not least because of the real chance of dangerous climate change.

However, many observers are critical of carbon pricing, often without being well informed about its unique advantages. Research suggests that resistance to innovative environmental policy—whether by citizens, firms, NGOs, or politicians—may be driven by lack of knowledge about how it exactly functions and which impacts it generates.[1] *Ex post*, that is, based on experience with implemented new policies, perceptions may dramatically change so that social–political acceptability increases.[2,3] Hence, imperfect information is an important obstacle to the implementation of carbon pricing, particularly as it allows political-ideological motivations to dominate.

Here, we argue that the main reason for carbon pricing is to achieve environmental goals at a reasonable cost, relatively low to that of other instruments. We provide many reasons for this, going beyond traditional static arguments about cost-effectiveness from environmental economics, by including relevant insights from energy research and innovation studies. Admittedly, many mainstream economic accounts of carbon or environmental pricing provide a more limited and technical perspective that often is not very accessible to noneconomists. Our paper offers a broader treatment that includes additional considerations, reflects a more heterodox and critical perspective on carbon pricing, and adopts a more multidisciplinary angle. We further briefly address some core political economy issues associated with carbon pricing, that is, reasons for why widespread implementation of such an instrument is not observed in reality.[4] This involves attention for distributional equity, lobbying, co-benefits, international coordination of policy, and motivational crowding in/out. While most arguments we consider have received ample attention in the literature, a comprehensive and synthetic treatment is missing. By summarizing all main arguments in favor of carbon pricing, this paper therefore fills a gap. It offers an accessible and nontechnical synopsis of the need for carbon pricing in a post-Paris world. This hopefully contributes to the debate on carbon pricing improving in quality and having more impact on political decision-making.

GENERAL IMPLICATIONS OF CLIMATE CHANGE CHARACTERISTICS FOR POLICY INSTRUMENTS

Climate change possesses several characteristics that must be accounted for in the formulation of climate policies to guarantee their effectiveness. Sources of anthropogenic GHG emissions are diverse and cover all economic sectors. Emissions arise principally from the combustion of fossil fuels, in very distinct activities, including resource extraction, production, consumption, transport, and waste management activities. This explains the heterogeneity of the many abatement options and associated costs. The GHG emissions accumulate in the atmosphere with residence times stretching from decades to millennia. Therefore, abatement incentives should last through time and be dynamic, that is, responsive to economic and technological change. The location of GHG emissions does not affect climate change as GHGs mix uniformly in the atmosphere. Hence, a reduction of emissions has the same global effect independently of the distribution of abatement efforts across space. Mitigating climate change lacks a simple end-of-pipe solution. Even though carbon capture and storage technologies may be part of the solution, these apply especially to large point sources and thus cannot provide an overall answer. Indeed, combating climate change represents such an immense and immediate challenge that relying on the promise of one option would be very risky. Instead, many options are required, including altering the composition of demand (using less energy), structural change in the composition of the economy (dirty vs cleaner sectors and products, and different input mixes in production), low-carbon transport, more energy-efficient technologies, and low-carbon (notably renewable) energy sources. Finally, particularly challenging for international negotiations is that abatement activities are generally costly and contribute to a global public good, meaning that others can benefit from them without undertaking any effort. This motivates the need to coordinate actions by countries and polluters to avoid free riding and international carbon leakage. Worldwide consistent policies are required to ensure

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cost-effectiveness of total abatement, fair economic competition between countries, and limited transboundary displacement of emissions.

We will argue that carbon pricing supported by a climate agreement is able to respond to these characteristics of climate change. This becomes clear by considering seven unique advantages of it, as explained in the next section.

SEVEN ARGUMENTS FOR GLOBAL CARBON PRICING

Carbon pricing affects emissions by penalizing energy sources in proportion to their carbon content. It is easily applicable to emissions coming from energy use, but can be extended to emissions arising from land use changes and other sources. In what follows we present the most important arguments in favor of carbon pricing.

Argument 1: As Carbon Pricing Alters Relative Prices, Firms and Consumers Automatically Internalize Global Warming Effects

Carbon pricing changes relative prices of all goods and services in accordance with the Polluter Pays Principle. As a consequence, when making decisions that cause GHG emissions, firms, consumers, and investors consider not just their private costs and benefits, but also the social costs associated with (direct and indirect) emissions generated in every phase of the product life cycle, from resource to waste. The entire economy then becomes less carbon intensive, since all consumers and producers will adjust their decisions to prices corrected for the climate externality. To obtain the same result with nonprice instruments would require that the regulator possesses all relevant information about emissions and abatement options to control in detail all polluting processes and behaviors. This would evidently be extremely difficult and imply a huge cost of governance.

Carbon pricing means that the prices of fossil energy fuels will adequately reflect the carbon content of these fuels. As a result, industries that use more carbon-intense fuels will face higher input costs and thus ask higher output prices from their customers. In turn, sectors using these outputs as inputs will also see their output prices go up. Finally, consumers buying products or services from the latter sectors will confront higher prices as well. As all these agents are motivated to purchase the cheaper input, product or service, a shift will occur to options with relatively low direct and indirect emissions. In other words, with a fairly simple carbon-pricing policy on fossil fuels each price in the economy will be corrected so as to reflect in some way the overall CO_2 emissions effect of the associated good or service. This means that no economic decision escapes the regulatory effect of carbon pricing—it is a systemic solution. This does not mean carbon pricing is the complete and only solution: as discussed in the *More Than Carbon Pricing* section, complementary instruments are needed, because of informational failures and bounded rationality, among others.

Argument 2: Carbon Pricing Accounts for Heterogeneity of Emitters, Which Reduces the Overall Abatement Cost

Compared to other types of instruments, carbon pricing can address the vast heterogeneity of GHG emitters, thus helping to minimize the cost of pollution control. Heterogeneity might result from firms producing diverse goods or having distinct technologies, and thus different emissions per unit of output, which translates into unequal marginal costs of pollution abatement. Under perfect information and substantive rationality, all polluters should choose that level of emissions abatement for which the associated marginal cost equals the carbon price. Hence, with a carbon price signal, the marginal abatement costs would become equal among all polluters, implying that a given level of abatement is met at least global cost. No other instrument than pricing is able to realize the same outcome. Since polluters show inertia or are not always perfectly aware of available abatement technologies and associated costs, one should expect the global cost to not reach the exact lowest level. Nevertheless, empirical research suggests that reliance on nonprice policy instruments often leads to considerably higher abatement costs.[5,6] The reason is that such instruments are less effective in covering diverse sources of emissions. For example, it is impossible to implement technical standards for the millions of technologies and products worldwide, and moreover update these frequently to account for nonstop technical innovation. To illustrate, two studies show, using different models, that a fuel economy standard for cars results in considerably higher costs of reducing CO_2 emissions than fuel taxes.[7,8] Note that older empirical studies found the abatement costs of uniform standards to be up to a factor 22 higher than those of pricing instruments.[9]

Argument 3: Carbon Pricing Provides a Continuous Incentive for Adoption and Innovation of Carbon-Efficient Technologies

Carbon pricing contributes to so-called *dynamic efficiency* as it stimulates innovation and adoption of technologies emitting less carbon. By increasing the cost of carbon-emitting technologies and activities, carbon pricing provides a financial incentive for consumers and producers to invest in technologies reducing emissions. This not only encourages more adoption of existing low-carbon technologies, but also indirectly promotes the development of new ones. Empirical evidence suggests a positive relationship between higher energy prices and the development of more energy-efficient technologies.[10] Compared with emission or technology-based standards, carbon pricing provides a continuous and stronger economic incentive for adoption of, and R&D on, improved abatement technologies. Econometric studies find that under stable energy prices, innovations generally reduce consumer prices, while after oil price hikes, they tend to make equipment more energy efficient.[11] This suggests that carbon pricing is an essential element of a policy package aimed at redirecting technical change towards the cleaner goods and ways of production. Further support for this comes from a comprehensive theoretical analysis.[12]

Examining the effect of the European carbon market (EU-ETS) on innovation, one study finds that carbon pricing is responsible for a 10% increase in clean innovation (measured by patents), in spite of the relatively low prices experienced so far.[13] Another study provides additional evidence on the innovation effects of EU-ETS.[14] Both confirm the results of an earlier patent-based study that energy prices have the largest inducement effect on energy-related innovations.[15] A third study analyses 3412 firm-level patent data from 80 countries for the car industry between 1965 and 2005, concluding that firms tend to innovate more in clean technologies when they face higher tax-inclusive fuel prices.[16]

Corrected prices are essential to rapid innovation in the right direction, as relative prices steer innovation opportunities and associated investments. This aspect is underappreciated in many discussions about technological change and climate change, where pricing is downplayed as if innovation/diffusion subsidies and other innovation policies, such as information provision or stimulating cooperation between innovators, were sufficient. To fully appreciate the subtlety of this point, it should be recognized that rather than current carbon or energy prices, expectations about future prices are relevant.[17] Of course, a high carbon price today acts as a signal for the near and more distant future, so that it will contribute to stimulating investments and R&D with the aim to reduce dependence on high carbon energy in all sectors of the economy.

Argument 4: Carbon Pricing Represents the Most Effective Way to Limit Energy/Carbon Rebound

The issue of energy rebound and how carbon pricing could mitigate it has received little attention in the public debate on carbon pricing. One reason may be that this argument was neglected by previous comprehensive reviews of environmental policy analysis.[18,19] In line with this, rebound has so far not been considered a standard criterion in environmental policy analysis.

Rebound denotes that energy conservation, including through adoption of more energy-efficient technologies, can indirectly create additional energy uses and associated emissions. Hence, the net conservation effect will be lower than the initial energy savings—or even negative in some cases, known as Jevons paradox. Rebound involves diffusion of technologies as well as various economic mechanisms. Technological advances and improvements in energy efficiency tend to lead to a direct reduction in energy consumption. However, given the improved efficiency, the energy services—for instance, traveling by car—become cheaper, which stimulates more intensive use of these services. Moreover, money saved due to more energy efficiency will increase spending on other goods and services, and hence associated energy use and emissions.[20]

Compared to other policy instruments, opportunities for such rebound effect are limited if carbon pricing is in place, because it is a systems approach that reduces rebound consistently across all carbon-intensive goods and technologies.[21] Such pricing would discourage money savings due to energy conservation to be spent on energy-intensive goods and services, as the latter will have a higher price due to carbon pricing. Empirical evidence suggests that such 're-spending rebound' is non-negligible and deserves serious attention in policy design.[22] Furthermore, in many cases, carbon pricing can reduce absolute rebound due to the direct rebound or intensity effect, because it may partially compensate the fall in the user (fuel) cost due to implementing more energy-efficient technologies (as in transport[23]). In these circumstances, the direct rebound effect on demand, in

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absolute terms, will be lower than in a situation without carbon prices as then initial demand is higher.

Carbon pricing will further ensure that consumers automatically, without even realizing, make a trade-off between the individual benefits of new or higher energy consumption due to rebound and related climate change damages.[24] Indeed, carbon pricing will mainly discourage rebound associated with a price correction for environmental damage costs exceeding direct individual benefits of the respective consumption decision.

Argument 5: Global Carbon Pricing Curtails Emissions Leakage Between Countries

An international carbon price covering all countries and sectors would ensure that there are no emission leakages or spillovers, that is, increases in carbon dioxide emissions in some countries as a result of emissions reduction in others.[25,26] The mechanisms through which this occurs are relocation of pollution-intensive industries and shifts in comparative advantages that alter international trade patterns, both driven by relative cost increases in countries with stricter regulations. Although some empirical studies suggest modest competitiveness effects of distinct environmental/climate policies, this will not necessarily be the case under scenarios with stricter but differentiated national policies, conceivable under the Paris climate agreement.[27] With a global carbon price, relative prices for all carbon-intensive products will be consistent among all countries worldwide, guaranteeing the absence of carbon leakage.

Obtaining such an ideal situation with no leakage would require effectively addressing the incentives to free ride. Various ideas have been put forward on how to overcome free riding in international negotiations.[28–33] In the absence of a global agreement to implement a carbon price, unilateral climate policies by individual countries (or regions) confront two main problems: loss of international competiveness, which discourages political support for a stringent unilateral climate policy; and carbon leakage, which reduces the effectiveness of any unilateral policy. Once a country applies carbon pricing on its domestic goods, it could in principle also apply it to imported goods, through a carbon-motivated border tax adjustment or requirements of acquisition of emission permits by importers when the policy is a cap-and-trade system.[34] This would level the playing field in the sense that comparative disadvantages due to carbon pricing would be reduced or even annulled. Several studies discuss technical aspects of carbon-motivated border tax adjustments, and on how they can be made consistent with World Trade Organization (WTO) rules.[35–38] In PE issue 4 in the section on *Political Economy Issues*, we will discuss the political economy aspects of free riding and possible strategies to overcome it, to achieve international coordination of climate policy, or even an effective climate agreement.

Argument 6: Carbon Pricing Decentralizes Policy, Reducing Regulators' Need for Information

Carbon pricing is consistent with flexibility and autonomy of choice, allowing emitters to freely change their behavior to reduce their costs. They can opt for emitting and paying any charges or taxes associated with emissions, or for undertaking a variety of activities, immediately or after relevant investments, to abate emissions. Carbon pricing thus means decentralization of policy, with associated low information needs and administrative costs. In addition, carbon pricing implies low transactions costs for firms, as, unlike eco-labeling, it requires no separate life cycle analysis to account for all carbon dioxide emissions of products and services. Instead, firms will integrate carbon prices in existing cost-accounting systems of their products and services.

Argument 7: Carbon Pricing Takes into Account that in Making Purchasing Decisions, most Consumers are most Influenced by Prices than by Environmental Concerns

Even if one is environmentally conscious, it is impossible to perfectly know which goods to buy and in what amounts to achieve environmental goals. It is, moreover, unthinkable that one can voluntarily contribute to all public goods in the world.[39] Even though many people would like to contribute at a personal cost to a more responsible use of the natural environment, such cooperative behavior frequently depends on the perception of what others will do.[40] The fact that an individual action alone has a negligible impact tends to discourage most people to undertake these voluntary actions. Moreover, many consumers are not particularly environmentally conscious in their purchase behavior, being sensitive to personally salient concerns, notably financial considerations, when making purchasing decisions. An effective climate policy has to reach out to this group. Carbon pricing is capable of doing this as it naturally intervenes in a core element of markets, namely prices of goods and services. It does so without the

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need for people to act altruistically, show voluntary environmentally benign behavior, or have the ability to handle much information about products as in the form of eco-labels. This does not deny proenvironmental behavior.[41,42] There is no clear evidence, though, that voluntary action can overcome very large differences in prices between green and dirty products/services, nor that it applies to a large group of consumers. Of course, policymakers are encouraged to leverage cooperative behavior when they have the opportunity to do so, but this approach cannot represent the main solution to climate change. Probably the most relevant voluntary behavior is that voters choose politicians who will strike a climate agreement that supports effective climate policies in all countries (see PE Issue 4 in the section on *Political Economy Issues*). Once implemented, carbon pricing does not require proenvironmental behavior. Nevertheless, the evidence available so far suggests that, if anything, proenvironmental behavior makes carbon pricing more effective, which is all good for climate policy (PE Issue 5 in section on *Political Economy Issues*).

MORE THAN CARBON PRICING: INNOVATION POLICIES, INFORMATION PROVISION, AND OTHER INSTRUMENTS

As already hinted at in Argument 3 in the previous section above, as carbon pricing and technology policy are largely complementary mechanisms they should both form part of a climate policy package. In the words of Bowen[43]: 'Other policies are needed, too, particularly to promote innovation and appropriate infrastructure investment, but cannot be relied upon by themselves to bring about the necessary reductions in emissions. Carbon pricing is crucial.' While carbon pricing can internalize the global warming externality, innovation subsidies are needed to internalize the positive, knowledge externalities of innovation, to promote escape from lock in, and to keep promising but still expensive options open.[44,45] With only carbon pricing, there is a risk of a lock in of currently cost-effective technologies (e.g., wind energy) while promising, but more expensive options in early stages of development may not survive (e.g., certain solar PV technologies). On the other hand, fostering a low-carbon transition through innovation and/or adoption/diffusion subsidies, that is, without carbon pricing, is extremely difficult, given that the emissions externality would not be internalized. Even when clean technologies develop and become less expensive, emissions would then be insufficiently discouraged. As soon as renewables were to become competitive, they would likely trigger responses by fossil-fuel markets in the form of lower fossil-fuel prices, thus making the attainment of climate goals more difficult. This type of outcome is a special case of what is known as the Green Paradox.[46–49]

Contrary to carbon pricing, subsidies aimed at stimulating adoption and diffusion of renewable energy do not target exactly the emission externality and moreover generate a burden for public finances.[50] Nevertheless, it may be hard to convince the public of how ineffective they may be in changing behavior. Yet, recent evidence in promoting renewables suggests that the implicit carbon price of subsidies for adopting solar energy is in the order of magnitude of 550 €/tCO_2 for the period 2006–2010 in Germany[51] and of 1000 €/tCO_2 from 2008 to 2011 in Italy.[52] These amounts are considerably higher than any currently discussed carbon prices, indicating that a counterfactual world with carbon pricing would for the same overall cost have achieved much more carbon dioxide emissions reduction.

In view of informational failures and bounded rationality, carbon pricing may be supplemented with mechanisms that aid households and businesses respond effectively to market signals and incentives.[53] Bounded rationality involves a broad set of behavioral features, such as decision heuristics, habits, conformism, imitation, status seeking, intertemporal choice, effects of information framing, and other-regarding preferences. The associated literature on policy design provides especially useful advice for information framing, on choice options (e.g., presenting a greener product as the default option, or providing information about how many neighbors already purchased it), or on explaining climate policy to voters (e.g., when framing a tradable permit system, rather than employing the term 'permits,' which stresses the interpretation of 'right to pollute,' one might refer to 'emission penalties'[41]).

In addition, information provision to citizens and firms about the opportunities to reduce GHG emissions would increase the impact of carbon pricing.[54] Recent research suggests that the price elasticity of demand may be higher with long-lasting carbon taxes than with temporary price fluctuations.[55–58] In view of this, media coverage and communication campaigns might aim at improving public understanding of the need for carbon pricing, clarifying it is meant to signal carbon-intensive goods and services. Information might further stress it is a permanent measure, thus limiting uncertainty about future prices for consumers and investors.[59]

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The above list of considerations regarding complementary policies is not exhaustive. Well-tailored policies, not necessarily based on prices, are needed to control emissions from sources other than energy production and use, such as land conversion, forestry, or landfill emissions. Ideally, pricing nonenergy sources of GHG emissions would allow lowering even further the cost of climate policy,[60] but this may be relatively hard to do in practice. Another aspect of complementary policy is removing existing market imperfections to improve the performance of carbon pricing. For instance, one study compares energy efficiency standards with carbon pricing through cap-and-trade and find that the differences get less pronounced if there is interaction with existing taxes on inputs other than energy and carbon, or if there are preexisting tax distortions, as is common in the case of capital.[61] By removing such distortions, carbon taxes would become even more effective.

Finally, not all complementary policies or measures are desirable. To illustrate this, we highlight that the effectiveness of carbon taxes is, contrary to what many believe, not dependent on the use of revenues for funding 'environmental projects.' It is quite common, though, to hear in public debates the idea expressed that revenues of environmental taxes should always be used for the environment. But this is not supported by insights from environmental economics. Carbon taxes are regulatory, not financing instruments. Of course, earmarking carbon tax revenues, or revenues of auctioned emission permits, for environmental projects or other issues, can be done to increase the acceptability of carbon pricing, but one should always bear in mind that its main objective is altering behavior. In the next section, we address the question of acceptability in more detail.

POLITICAL ECONOMY ISSUES ASSOCIATED WITH CARBON PRICING

This paper does not aim at addressing exhaustively the political economy (PE) of carbon pricing. We nevertheless briefly discuss six issues, namely distributional equity, lobbying, co-benefits, international policy coordination, crowding in/out, and long-term commitment.

PE Issue 1: Distributional Consequences of Carbon Pricing

Much resistance against carbon pricing is motivated by concerns that it will be inequitable, that is, have regressive distributional effects in terms of income or consumers' purchasing power. Of course, any serious climate policy could have similar, undesirable distributional impacts. In the case of carbon pricing, however, regressive impacts are not inevitable. They can be avoided through appropriate policy design or complementary measures. Moreover, when considering the distributive consequences of carbon pricing, it is important to compare these to alternative scenarios, notably business-as-usual (no climate policies) and climate mitigation policies with alternative, and less effective, instruments. For instance, many studies show that unmitigated climate change impacts would be unequal among countries and that poorest countries will be more affected than richer.[62]

Paradoxically, carbon pricing provides an excellent instrument to address undesirable distributional consequences—notably if taking the form of carbon taxation, but also of emissions trading, if initial permits are auctioned or sold. The reason is that it will generate public revenues that can be used to compensate low-income households, for example, through tax reductions for low incomes or energy poor households, or lower value-added tax (VAT) rates for products serving basic needs.[63–65] Progressive effects can also be obtained by lump sum redistribution, which represents the simplest and administratively less burdensome way of recycling revenues from carbon pricing.[66–68]

Any remaining distributional impacts of carbon pricing have to be compared with those resulting from climate change or other climate policy instruments. For example, technical standards will not necessarily guarantee an equitable distribution of emissions reductions and associated monetary and welfare costs. In particular, they will also raise costs and thus prices, but not generate extra public revenues that could be used to lessen perceived unfair distributive impacts. In a review of arguments and empirical studies, one study warns that assessing distributional effects of environmental policy (any instrument, not only pricing) is a difficult task, as it involves six elements: (1) higher prices of carbon-intensive products, (2) changes in relative returns to factors such as labor, capital, and resources, (3) allocation of scarcity rents from a restricted number of tradable permits in the case these are initially freely distributed, (4) distribution of the benefits from improvements in environmental quality, (5) temporary effects during the transition, and (6) capitalization of all those effects into prices of property values (land, buildings, and houses).[69] A full assessment should account for all of them, which clarifies the huge challenge to comprehensively address distributive impacts of policy. It means one should be careful in quickly judging a particular instrument, like

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carbon pricing, negatively from the angle of equity. It should further be noted that in the case of climate change, the beneficiaries of reducing emissions are future generations, notably people living in poor countries. Hence, carbon pricing can contribute to both intra- and intergenerational equity.

A general finding of the literature on acceptability of climate policy, and in particular of carbon taxes, is that people tend to have a strong preference for designs that protect low-income households.[70–73] Concern about income inequality is among the main reasons why 92% of voters (more than two million people) in a public ballot held in Switzerland in 2015 rejected a proposal for an energy tax to replace the national VAT.[74] The authors of this study show, using a choice experiment administered at the same time of the ballot, that acceptability is much higher when a progressive energy tax is proposed, provided that information on its distributional properties are made salient.

When considering redistribution effects of climate policies, one should realize that a subsidy scheme for adopting renewable energy—not to be confused with innovation subsidies as discussed in the *More Than Carbon Pricing* section—may be regressive as well, namely when it involves a considerable transfer of money to homeowners, notably for installing solar PV panels on roofs. This type of scheme was introduced in a number of countries (e.g., Germany and Switzerland) as carbon pricing turned out to be unpopular. But, as argued, subsidies do not necessarily perform better, neither on (cost-)effectiveness nor on equity. The distributional effect should be carefully analyzed in each specific case as it will depend on the precise design of the subsidy scheme.

PE Issue 2: Carbon Pricing and Lobbying

There is evidence that lobbying by energy-intensive industries contributed to prevent the implementation of carbon pricing in several countries,[75–78] and may have influenced voters' perceptions about its potential drawbacks.[79] Even where carbon-pricing schemes were implemented, energy-intensive industries have in many countries through lobbying managed to receive a very favorable treatment, resulting in less effective policies.[77,80,81]

Energy-intensive industries are, however, no longer the only actors active in lobbying: we now observe a situation in which 'green organizations' oppose 'brown industries.'[82] For instance, evidence from British Columbia's carbon tax stresses the importance of environmental organizations in successfully spreading support for it.[2] Environmental organizations need to stress, though, the benefits of carbon pricing, and be informed about potential solutions to limit the drawbacks. Following decades of lobbying against carbon pricing, misunderstandings of, and ideological resistance against, this instrument have permeated the public arena.

Recent developments including the Paris Agreement seem to have shifted the opinion of many important businesses in favor of carbon pricing. Indeed, 150 companies that report to the Carbon Disclosure Project (CDP) are using internal carbon pricing as a tool to internalize carbon dioxide emission costs and drive investments in emissions abatement. Resulting carbon prices range from US\$6 to US\$89/tCO_2 equivalent.[83,84] A recent survey realized among more than 100 executives of large companies around the world suggests that support for carbon pricing is strongly on the rise.[85] Almost half of the executives now declare to be in favor of carbon pricing, while another large portion states to be not against it. Moreover, a significant portion of respondents expects future climate negotiations to bring about some form of carbon pricing, and is ready to prepare for this scenario.

In countries that are credibly pursuing their commitments to the Paris Agreement, industries would do well to lobby for instruments, like some form of carbon pricing, that provide them flexibility in choosing the means of abating emissions. Many businesses already realize that carbon pricing is not a bad option as it leaves them a free choice between paying for emitting or abatement, while postponing action only makes the cost of achieving a given target higher.[86,87] However, because carbon taxes and auctioning of permits means considerable money transfer from enterprises to public administrations, one should expect many firms to continue lobbying against carbon pricing.

PE Issue 3: Carbon Pricing and Co-Benefits

Another political economy issue is local co-benefits playing in favor of carbon pricing. Examples of co-benefits are health benefits of clean air due to less local pollution, reduced energy costs due to improved energy efficiency, or energy security and less dependence on fossil energy imports due to more variety in energy sources, including renewable energy.[88,89] Cobenefits also arise from other climate policies. However, since carbon pricing should be expected to be more effective in emissions reduction, as argued in the *Seven Arguments for Global Carbon Pricing* section, its co-benefits are likely to be larger. In this respect, we support those who argue that co-benefits can be a reason for countries to implement carbon

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pricing unilaterally, that is, in the absence of a binding climate agreement.[90] A relatively high carbon price, up to 63$ per ton of CO_2-equivalent in the case of China, could be justified based only on local co-benefits, that is, without accounting for climate benefits.[91] The authors find that even for the United States, a carbon price of more than 30$ per ton of CO_2-equivalent is warranted by local co-benefits. Since co-benefits can be reaped in the short term and be appropriated by the country that implements carbon pricing, drawing more public attention to them could increase its acceptability.[73,92,93] Carbon pricing may not be the best way to reduce local pollution, and other complementary policies precisely targeting harmful local pollutants might be preferable. But as long as the latter policies are not, or unlikely to be, implemented one can count reduction of local pollution due to climate policy as a relevant cobenefit.

PE Issue 4: Carbon Pricing and International Policy Coordination

The literature offers various suggestions to overcome free riding and achieve international coordination of carbon pricing. Nordhaus[94] proposes a radical solution to deal with free riding and carbon leakage, taking the form of a climate club, the members of which implement significant trade tariffs on imports of noncomplying countries, regardless of the carbon content of the traded goods. These would serve as incentives for nonmembers to join the club. Similarly to carbon border tax adjustments, this proposal creates an incentive for other countries to implement carbon pricing as well.

One proposal builds on the standard idea of a carbon border tax and, to clarify that it is motivated by environmental concerns and should not be interpreted by nonclub members as a protectionist measure, suggests to complement it with so-called *revenue-recycling offsets*.[95] This means that while the tariffs reduce import demand for the carbon-intensive goods, the associated revenues of the tariffs are unconditionally returned to the exporting countries from where the products subject to the tariff originate. This would signal that the tariffs are meant to support climate policy, and are not a disguised form of protectionism or aimed at raising public revenues.

Another political economy issue relates to what type of effective climate policy is easier to negotiate globally. A global carbon price would be an ideal basis for negotiations aimed at worldwide commitment as it is easy to agree upon, relatively fair (pending on equitable national and international redistribution of receipts, see below), consistent with energy policies already in place (e.g., fossil-fuel taxes are common in most countries), and requiring relatively little information (notably compared with an agreement on climate technology standards).[96] Two relevant insights should be added to this.[97] First, whereas quantity negotiations involving n countries imply dealing with an at least n-dimensional coordination problem, focusing on a global carbon price comes down to a much simpler, one-dimensional negotiation challenge. Second, a global carbon price benefits from a self-enforcement mechanism, given that incentives are better aligned because the desire to internalize the climate externality offsets the basic urge of countries to bargain for a low national carbon price. Such a mechanism is missing in the case of national mitigation contributions as characterized the Kyoto protocol and the Paris Agreement.

PE Issue 5: Carbon Pricing and Motivational Crowding In/Out

Motivational crowding out may arise when financial incentives or punishments undermine intrinsic motivations to contribute to public goods,[98–100] including environmental policy or public goods issues.[101] This has stimulated critiques that (carbon) pricing may be less effective than expected *ex ante*, because it would reduce proenvironmental behavior of some individuals.[102] However, various studies suggest that at the aggregate level carbon taxes are, if anything, more effective than predicted.[55–58] Carbon pricing may actually contribute to motivational crowding in.[103] At the microeconomic level, we are not aware of any occurrence of considerable crowding out due to carbon pricing. One may wonder why there is so much concern about motivational crowding out.[104–106] Backed by experimental data and a survey among economists, a recent study concludes that a plausible reason is that certain influential, early publications as the ones mentioned above have been interpreted as demonstrating that crowding out was a general phenomenon, whereas it only applies to particular settings.[107]

PE Issue 6: Carbon Pricing and Long-Term Commitment

An effective climate policy requires that there is long-term commitment for a credible carbon price signal. This can be achieved with both options as discussed in the *Two Ways of Implementing Carbon* section. The cap-and-trade system provides a guarantee for long-term commitment with policy goals as the system, once in place, will assure a carbon price that keeps emissions within the cap. If, on the other hand,

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governments pledge to a carbon tax schedule over time, supported by an international agreement, then commitment is arranged too. One can observe that carbon tax rates have been kept constant or gradually increased over time in all countries in which they have been applied. Likewise, in every later phase of emissions trading schemes, increased stringency was strived for. This is illustrated by the EU-ETS, which has broadened its scope both in term of number of countries and of activities covered, and has progressively used auctioning instead of free allocation.[108] To date, the only meaningful example of policy reversal is Australia, whereas the 'carbon club' of countries applying increasingly stringent policy is steadily increasing in size.[77,84] This underpins long-term commitment regarding a carbon price.

While credibility of a long-term policy commitment is not easy to achieve, this may improve when policy reversals are discouraged by introducing commitment devices. To illustrate, the well-known carbon tax of British Columbia was introduced with a commitment device imposing on the regulator a predefined tax escalator (i.e., a set path for future price hikes) and the obligation to reduce revenues from other taxes (mainly on income) to compensate for carbon tax revenues. The incentive effect of this was confirmed by a recent review.[2] Switzerland has opted for an automatic carbon tax adjustment system. If emissions levels are above an emissions path that has to be followed to reach the abatement objective as specified in the CO_2 Act, then the carbon tax rate is automatically raised. This ensures that carbon tax rates are not affected by political cycles. Incidentally, one should realize that commitment to any serious climate policy will be difficult and require appropriate design, that is, this problem is not unique to carbon pricing.

TWO WAYS OF IMPLEMENTING CARBON PRICING GLOBALLY

One can achieve a unique worldwide carbon price using a global carbon tax or a global emissions trading system. While the first approach sets the carbon price directly through an administrative decision, the second sets a cap on emissions and allocates the emission allowances between emitters. Emissions trading then results in a carbon price. Both approaches satisfy the general favorable properties mentioned in previous sections. In addition, each approach has particular advantages and disadvantages, as discussed below. Hence, there is not an unequivocally better alternative, which explains why each option has its own advocates.

Carbon Pricing Through a Carbon Tax

There are two possible international carbon tax designs, both of which require an international climate agreement. One is a global carbon tax, the revenues of which would be collected centrally, for example, through the UNFCCC Secretariat, and subsequently redistributed among countries in relation to their demographic weight or other criteria. Despite its political difficulty, this alternative has the advantage of a single worldwide carbon price. It would, moreover, generate positive international redistributive effects given the positive correlation between per capita GHG emissions and per capita income. A main advantage of a carbon tax is that it generates revenues over time that allow complementing it with redistribution policies to ameliorate any undesired inequitable effects of the tax. In addition, a part of the carbon tax revenues might be allocated to innovation and adoption/diffusion subsidies or to the provision of green funds financing environmental projects or adaptation measures in poorer countries. Public acceptability studies show that using carbon tax revenues in these ways can often increase their social and political acceptability.[1]

While a global carbon tax would imply financial transfers from rich to poor countries, one should realize that any serious climate policy, price-based or not, will require such financial transfers. However, as carbon taxes as well as carbon markets—through initial sales or auctioning of permits—generate considerable public revenues, with carbon pricing rich countries are more likely to provide financial support to poorer countries than with other policy instruments (notably quantity regulation or technical standards), as these do not generate public revenues. Absent any transfer, carbon prices should be lower in poor countries, as the marginal valuation of consumption is higher there, because of diminishing returns of consumption in utility, and thus the marginal cost of abatement should also be lower.[109] However, as distinct carbon tax levels between countries reduce effectiveness, due to carbon leakage (see Argument 5 in the section on *Seven Arguments for Global Carbon Pricing*), transfers—which in effect are motivated by the same argument of different marginal values of consumption—are preferable.

An alternative to a global tax is an international agreement that partially harmonizes national carbon taxes, requiring a minimum common rate. This would contribute to the cost-effectiveness of the allocation of global abatement efforts among countries. In comparison with a genuine global tax, under this option redistribution of revenues between countries would be more complicated. In the near term,

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measures as discussed in PE Issue 4 in the section on *Political Economy Issues*, namely carbon border tax adjustment or more generally trade sanctions, could reduce free riding and promote wide participation in an international agreement. As a carbon tax might be difficult to apply straight away in some low-income countries, in a preliminary stage, one could aim for at least a reduction in fossil-fuel subsidies equivalent to the increase in prices in developed countries.[110] The avoided expenditures could be used to ameliorate any negative distributive impact of such policy reform. This might facilitate a broad participation of developing countries in a first stage and their adoption of a harmonized carbon tax in a later stage.

Carbon Pricing Through Emissions Trading

An international emissions trading system could also take different forms. A truly global market would cover all emission sources, giving rise to a single carbon price worldwide. This would assure cost-effectiveness of emissions abatement at a global level. This works as follows. The emissions cap set by the regulator would be motivated by an agreed upon long-term climate goal (such as maximally 1.5°C or 2°C global warming). A consistent number of permits is then given, sold or auctioned among the emitters from all countries. Global emissions trading among emitters then translates the scarcity of permits into a global carbon price. This price will be affected by incomes, demand-price relations for carbon-intensive goods and services, and technologies in the global economy. This means individual agents do not need to have a long-term vision or goal—this is only required from the global regulator in order to set an adequate cap. The carbon market price will then ensure that all decisions by all economic actors in the global economy are in line with the long-term climate goal.

Nevertheless, creating such a global emission trading system is very challenging in both political and institutional terms. An ideal international treaty would fix a global emissions cap and then distribute allowances between countries, which could trade them, resulting in a global carbon price. If all countries distributed their allowances among their firms, a cost-effective international market could be established. However, similarly to carbon taxes, it would probably be politically easier to start with distinct emissions trading systems covering certain countries and regions (like the EU), and integrate these globally in a subsequent stage to ultimately cover all countries and sectors. Indeed, various cap-and-trade systems have been developed in North America, Europe, and Asia, forming a fertile basis for integration at a larger, global scale. There are already examples of linkages between emissions trading systems, such as those that exist between California and Quebec.

As in the case of carbon taxes, some developing countries may be reluctant to participate. A possible approach is to link the carbon markets of developed countries to an emission-reduction-credit (ERC) system based on projects reducing emissions in developing countries, thus exploiting their low-cost mitigation opportunities.[110] Such a design would open the door to a truly global carbon pricing system in these countries. However, an ERC system is still very controversial as it faces various problems, such as assuring 'additionality' (abatement that would not have occurred without carbon pricing) and allowing for perverse, counterproductive effects.[111] Problems of this kind should be analyzed before ERC can be considered a viable option.[112] Current controversies, and ethical-equity considerations, have discouraged the use of the ERC system in the EU-ETS.[108] Similar controversies concern the Californian ETS. A recent paper[113] tackles the question of the acceptability of international carbon offsets experimentally. Participants face the decision to fund domestic or international reforestation programs, knowing that the same emissions reductions are provided by a local or an international tree, but domestic trees are much more expensive. Randomized treatments making even more salient the price differential contribute to the popularity of international offsets, in particular among individuals with strong environmental preferences, suggesting that transfers between developed and developing countries may be facilitated by stressing the related environmental gains.

As with the redistribution of carbon taxes revenues, setting rules of allocation of allowances among countries and emitters in each country is a major hurdle, because they reflect implicit ethical and political choices. The grandfathering approach used in many programs favors large emitters and penalizes those who made mitigation efforts before the policy implementation.[114] As a result, there is now broader support for initializing systems through auctioning permits, also because it improves the efficiency of the overall tax and permit system, namely by using the auction revenues to reduce distortionary taxes.[115] As for carbon taxes, distributional concern would play in favor of either a redistribution of revenues from permit auctions based on the demographic weights of countries or the direct allocation of allowances on per capita basis. Hence, both could be progressive in terms of intercountry distribution and so address one of the criticisms to global carbon markets in particular and global carbon pricing in general.

Emissions trading systems have been criticized for their volatility, which may be an important handicap for long-term investments, as these depend not only on current prices, but also on expectations about future prices. However, carbon prices in emissions trading systems do not necessarily have to be extremely volatile. Price floors and ceilings (so-called ‘safety valves’) have been proposed to address the issue of volatility. The latter comes down to a mixed system, that is, a combination of tradable permits and a tax,[116] thus insuring against unexpectedly high costs, one may convince firms to comply with, and countries to participate in, carbon markets.[110]

CONCLUSIONS

We have presented seven reasons for using carbon pricing in climate policy:

1. It changes relative prices to reflect all direct and indirect GHG emissions of products and services so that firms and consumers will automatically internalize the costs to achieve a given emissions abatement goal.
2. It minimizes the overall cost of pollution control as it accounts for differences (heterogeneity) between polluters in terms of abatement opportunities and costs.
3. It contributes to dynamic efficiency, because it provides continuous incentives for adoption and innovation of new technologies that emit fewer GHGs.
4. It is the best instrument to limit energy and carbon rebound in an effective way.
5. If it were to cover all countries and sectors, it would ensure that there are no leakages through international relocation of dirty industries and shifts in foreign trade patterns that merely replace GHG emissions from one country to another.
6. It implies decentralization of policy, with associated low information needs for regulators.
7. It builds on the empirical fact that when making purchase decisions, most consumers are more influenced by prices than by environmental concerns.

As a result, carbon pricing will be a very effective instrument, for a given cost of abatement. While the economic literature on environmental policy generally stresses the optimality of carbon pricing in terms of maximum welfare or minimal abatement costs, our arguments draw attention to the fact that carbon pricing is more effective, at a reasonable cost, in reducing emission than other approaches. This is especially true when it is combined with some form of innovation subsidies. This is not to deny the importance of the relatively low global abatement cost of carbon pricing compared to other instruments, but we believe that its high effectiveness in reducing GHG emissions has been somewhat neglected in many popular accounts, while it should matter equally for political feasibility. We stress that corrected prices are also essential for environmental innovation as they affect innovation opportunities. This is seriously underappreciated in the public debate on technological change and climate change. Here, pricing is often downplayed, while the erroneous view is widespread that to stimulate innovation and diffusion attention should be focused only on subsidies, or other innovation policies. But as argued, carbon pricing and innovation policies are predominantly complementary and hence an effective climate policy mix should include them both.

Many countries already have implemented policies to stimulate climate change mitigation, including carbon taxes and emissions trading schemes.[84,117] Some early examples of carbon taxes and emissions trading schemes may have been or seemed relatively ineffective, due mainly to excessive generosity in handling emissions allowances, very low tax rates, or exemptions. But this does not argue against the policy instrument. The observed lack of stringency was mainly due to a lack of effective international coordination of climate policies. Emissions pledges have been at the center of climate negotiations preparing for COP21 in Paris. We believe that negotiating around a single price will become easier as more countries get involved in carbon pricing and an increasing number of people become well informed about its unique advantages.

A concern sometimes raised is that uncertainty about the social cost of carbon (SCC), or assessing a monetary SCC value in the first place, translates into uncertainty about the appropriate value of a carbon price. While such uncertainty about the SCC indeed exists, support seems to be increasing for the view that it is higher than 100 US$ per ton CO_2, as indicated by recent surveys.[118,119] One should realize, though, that controversy about the SCC value is not at all a barrier in implementing a carbon price. If using cap-and-trade, the cap—set in accordance with a political climate or emissions goal like the two-centigrade target—will determine the adequate price

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level. If using a carbon tax, then a rising tax schedule has to be applied until the responses by consumers and producers are in line with the same climate goal. In other words, the reality of carbon pricing is not limited by academic controversies on the possibility of defining and estimating an optimal level of pollution. One can defend the necessity of pricing carbon and at the same time be rather skeptical about the concept of an optimal carbon price. Since we are now in a post-Paris world, the trajectory for carbon pricing is for the time being determined by the Paris goals. However, the national pledges of the Paris climate agreement are far from cost-effective, in the sense that some countries will have much higher marginal abatement costs than others, so that the global cost to reach the same emissions abatement objective will be unnecessarily excessive. Paris' pledges are merely a first step, insufficient by itself, to avoid dangerous interferences with the climate system. In view of this, our proposal is not to be satisfied with the Paris pledges and just achieve them through carbon pricing, but to go beyond the Paris agreement. A global carbon price would facilitate this, as it would achieve a not overly expensive outcome using an effective instrument.

In view of the seven advantages of carbon pricing and the additional considerations, including the various political economy issues, we should remove ideological barriers against such a critical element of an effective climate policy package. Anyone who is critical of carbon pricing needs to address these seven proarguments, and present an alternative policy approach that guarantees a similar effectiveness in reducing GHG emissions against reasonable cost. As we have argued, however, all alternative options are likely to result in considerably less effective, even though well intended, ways of regulating emissions and thus are likely to be unable to avoid dangerous climate change. We hope to have convinced the reader that among all instruments carbon pricing deserves the most serious attention from researchers, politicians, and citizens.

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