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Climate change policy and carbon pricing

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ABSTRACT

Carbon prices and carbon caps need to be set at levels that will deliver the reduction targets necessary to keep global warming under 2 °C, aspiring to 1.5 °C above pre-industrial levels, in line with the Paris Agreement. Given both the urgency of the situation and the heterogeneity across countries and sectors, switching caps and switching prices may be the answer.

1. Introduction

Internalizing the marginal external cost of greenhouse gas (GHG) emissions with an efficient carbon tax or an efficient cap-and-trade system, or a combination of both, carefully designed not to double-charge, was a sensible idea back in the 1990s. It is not any longer (Patt and Lilliestam, 2018; Tvinnereim and Mehling, 2018). Either system now needs to be based on emissions reductions targets as dictated by the science, and complemented with additional measures.

The Rio Summit took place in 1992, but it was not until 2015 that a legally binding international treaty on climate change, that included industrialized countries, economies in transition and developing countries, was finally adopted. The Kyoto Protocol, which was adopted in 1997 and came into force in 2005, was also a legally binding international treaty but it only committed industrialized countries and economies in transition to reducing their GHG emissions. China and India, for example, were not included. In addition, the US never ratified it, and Canada withdrew from it in December 2012 (United Nations, 2022), just before the end of the first commitment period, which ran from 2008 to 2012. To make matters worse, Japan, New Zealand and Russia never took part in the second commitment period, which ran from 2013 to 2020 (European Environment Agency, 2020). As a result, only a fraction of the world emissions was covered by the agreement.

Climate change policy interventions around the world have been, in general, not in line with economists' recommendations. In addition to this, the science of climate change has advanced at a faster pace than climate change policy. In this paper I argue that economics can now serve humanity by calculating the carbon prices and carbon caps that will ensure the required emissions reductions in time to reach net-zero by 2050, and thus avoid a global temperature increase of more than 1.5 °C above pre-industrial levels (Intergovernmental Panel on Climate Change, 2018, p. 12).

2. The economics of climate change

A standard result in environmental economics is that under perfect information, a system of Pigouvian taxes (set equal to the marginal external cost at the efficient level of emissions) and a cap-and-trade system (with the cap set at the efficient level of emissions) yield the same efficient outcome. Indeed, the same information is needed to specify the efficient tax or the efficient quantity (Weitzman, 1974, p. 478). If the efficient number of permits is made available in the market, their equilibrium price will be equal to the Pigouvian tax.[1] This, however, has not been the case in any of the emission trading schemes in operation around the world, including the European Emissions Trading Scheme (EU ETS), because the caps were mainly guided by politics rather than economics. Even if they had been guided by economics, they would have been set under imperfect information regarding both marginal costs and marginal benefits.

The 1990s saw an explosion of papers on the economics of climate

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[1] When there is uncertainty, however, the regulator may fail to set the efficient price or the efficient quantity. The cost of the error with taxes and permits will be the same if there is perfect information regarding marginal costs but lack of information regarding marginal benefits (Weitzman, 1974, p. 485). The cost of the error under taxes or permits will be different if there is lack of information regarding marginal costs, and will depend on the relative slopes of the marginal cost and marginal benefit functions around the optimal level (Weitzman, 1974, p. 485).

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change, which has continued to this day. Examples from the early 1990s in general economics journals include a Policy Forum in the 1991 volume of the Economic Journal, with an editorial by Greenaway (1991) and papers by Cline (1991), Nordhaus (1991) and Pearce (1991), a section on the Contributions of Economic Modelling to the Analysis of Costs and Benefits of Slowing Greenhouse Warming, from the 105th Annual Meeting of the American Economic Association, published in the May issue of the American Economic Review, with papers by Gaskins Jr. and Weyant (1993), Nordhaus (1993a) and Reilly and Hohmann (1993), and a Symposium on Global Climate Change, published in the Autumn 1993 number of the Journal of Economic Perspectives, with an introduction by Schmalensee (1993), and papers by Nordhaus (1993b), Weyant (1993), Poterba (1993) and Chichilnisky and Heal (1993).

As economists, we thought we had the answer to the problem, perfectly summarized in one of Nobel Prize Winner Nordhaus's papers: before rushing onto policy design and implementation it was important 'to weigh the costs and benefits of climatic change or alternative control strategies' (Nordhaus, 1991, p. 920). That was key, we thought. In the years that followed, economists devoted themselves to estimating marginal costs and marginal benefits, acknowledging the different assumptions needed and sources of uncertainty. Part of the exercise involved (and still involves) the calculation of the Social Cost of Carbon (SCC), which measures the cost of emitting an additional tonne[2] of CO_2 or its equivalent into the atmosphere today and adds the cost of the damage it causes over the time it stays in the atmosphere. This externality is the same regardless of where the GHG emissions originate (Dolphin et al., 2020, p. 475). The price of carbon therefore should be the same across countries and sectors (Tirole, 2012, p. 123), from a theoretical point of view. In an efficient equilibrium, the SCC should be reflected in carbon taxes or permit prices. The beauty of these ideas is that abatement costs would be minimized because emissions reductions would occur where it is cheapest.

We had debates over discount rates, perhaps best illustrated by the discrepancy between Nordhaus and Stern (Nordhaus, 2007), distributional weights, science uncertainty, and climate risks,[3] but, in general, we never departed from the premise that on economic efficiency grounds, policy had to be designed on the basis of internalizing the climate change externality at the margin. Having said that, there were some early voices of dissent, with a prominent one being the Stern Review, which pointed out that there was a "serious risk of major, irreversible change with non-marginal economic effects" (Stern, 2006, p. v).

More recently, Farmer et al. (2015) highlighted a number of issues which remain inadequately addressed by economic models of climate change, including uncertainty, aggregation, heterogeneity and distributional implications, technological change, and damage functions, which map temperature increases to economic damages.

The literature on the economics of climate change continues to focus on costs and benefits, the SCC, and efficient policy instruments. No agreement has been reached regarding what the value of the SCC is or should be (Ricke et al., 2018). After three decades of research on the economics of climate change, translation into policy has been slow and shy. Countries were reluctant to make bold commitments, especially until the 21st Conference of Parties (COP)[4] in 2015, when the Paris Agreement was adopted. The result is that global GHG emissions have continued to increase, as shown by the thick solid line on Fig. 1. The political economy of carbon pricing is partly to blame, and this is discussed in the next section.

[2] A "tonne" in this paper is a "metric ton", i.e., 1000 kg.

[3] See, for example, van den Bergh and Botzen (2015).

[4] The Conference of Parties (COP) is the decision-making body of the United Nations Framework Convention on Climate Change. All States that are Parties to the Convention are represented at the COP.

3. The political economy of carbon pricing

Although membership of international organizations or international institutional frameworks has a positive association with the presence of carbon pricing, as do higher national incomes (Dolphin et al., 2020), there are also a number of reasons why governments have been reluctant to adopt market-based policy instruments, and the instruments they have implemented have been seemingly inefficient (Lindsey and Santos, 2020). Some of these reasons include inability to make long-term commitments (especially until 2015, when the Paris Agreement was adopted), lack of coordination between governments, and susceptibility to lobbying (Lindsey and Santos, 2020). For example, countries with a high concentration of carbon-intensive production experience opposition to carbon pricing from such sectors (Dolphin et al., 2020) and often tend to be less active on climate change policy (Steves and Teytelboym, 2013).

Export-oriented sectors also typically oppose carbon pricing, as this can reduce their competitiveness in international markets and cause leakage. For example, under the EU ETS, industrial installations considered to be at significant risk of carbon leakage receive a higher share of free allowances compared to other industrial installations (European Commission, 2021).

In addition, some governments do not have the same (or sufficient) incentive to implement carbon pricing or caps, or indeed, reduce carbon emissions. China and India, the world first and third highest emitters, highly reliant on coal for electricity generation, put pressure and eventually managed to tone down the final text of the COP26 agreement, which was originally drafted to "phase out" coal (Rincon, 2021). The final text of the Glasgow Climate Pact (United Nations, 2021) contains a weaker commitment to "phase down" coal.[5]

Two issues with international climate change negotiations are that the very text is subject to lobbying, as just described, and that even when agreed, countries sometimes deviate from those international obligations, or submit pledges that are insufficient. One example is, again, that of China and India, whose emissions have continued to increase due to economic growth, as can be seen on Fig. 1, even though their Paris pledges are expected to be met (Watson et al., 2019).

Political acceptability is an important barrier in carbon pricing, and some economists are now also acknowledging that it is more important than efficiency itself (Klenert et al., 2018, p. 669). The bottom line is that policy makers often struggle to introduce carbon taxes or cap-and-trade systems. A number of carbon tax and cap-and-trade systems have been implemented around the world, but these are far from widespread (World Bank, 2021b, p. 14; Dolphin et al., 2020, p. 497; Parry, 2019, p. 18). In 2020, carbon pricing initiatives covered a mere 21.7% of the world GHG emissions (World Bank, 2021b, p. 14). In addition, the tax level or the cap has typically been set with political considerations in mind rather than on the basis of economic efficiency principles. Carbon prices in general are not high enough to trigger the necessary changes in demand and supply that will yield the required ambitious emissions reductions (Parry, 2019, p. 18; Hepburn et al., 2020, p. 2; World Bank, 2021b, p. 14). The carbon price required to meet the Paris targets would have been at least US$40–80 per tonne of CO_2 in 2020 (High-Level Commission on Carbon Prices, 2017) but in 2020 only 3.76% of global emissions were covered by a carbon price in that range or above (World Bank, 2021b, p. 25). The range is only an indicator, and the carbon price required in a given country to meet their Paris targets, can be different from that required in another country (Parry, 2019, p. 18).

4. The science of climate change

The science of climate change has advanced substantially in the last

[5] That said, this is the first time that a COP agreement explicitly mentions the reduction of coal.

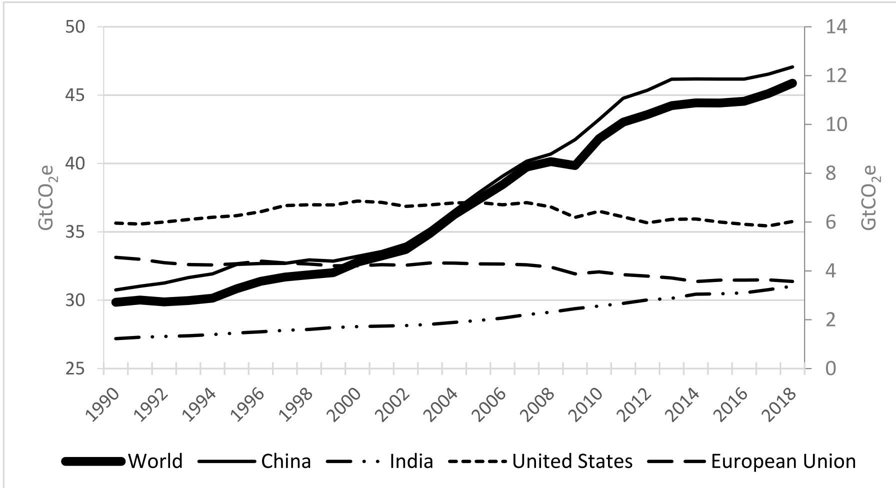

Fig. 1. Total GHG emissions ($GtCO_2$ equivalent).
Source: World Bank (2021a).

two decades and, although virtually all the analysis and results are probabilistic, there is much more certainty than there was back in the 1990s and early 2000s. Thanks to these scientific advances, there are now carbon budgets. A carbon budget is defined as the cumulative net amount of anthropogenic CO_2 that can be emitted before a global warming threshold is passed (Meinshausen et al., 2009; Rogelj et al., 2019; Intergovernmental Panel on Climate Change, 2021). There is widespread consensus that this threshold is 2 °C, and we should aspire to a target of 1.5 °C, as spelt out in the Paris Agreement (United Nations, 2015), in order to avoid the most damaging effects of climate change. The total carbon budget is always estimated starting from the pre-industrial period, and the remaining carbon budget is estimated from a recent specified date (Intergovernmental Panel on Climate Change, 2021, SPM-36).

There is a wide range of carbon budget estimates, mainly due to the use of different non-CO_2 climate forcing assumptions, methodologies, and models (Rogelj et al., 2019). In addition, carbon budgets are calculated on the basis of probabilities, and therefore, typically entail a range of values, each associated to a probability or probability range, such as for example those produced by Meinshausen et al. (2009, Table 1, p. 1161) or by the Intergovernmental Panel on Climate Change (2021, Table SPM.2, SPM-38). For example, the remaining carbon budgets from the Intergovernmental Panel on Climate Change (2021, Table SPM.2, SPM-38), estimated from the beginning of 2020, vary from 2300 $GtCO_2$, to have a probability of 17% of not exceeding a temperature increase of 2 °C above pre-industrial levels, to 300 $GtCO_2$, to have a probability of 83% of not exceeding a temperature increase of 1.5 °C. To have a 50% probability of limiting global warming to 2 °C and 1.5 °C, the remaining carbon budgets from the beginning of 2020, are 1350 $GtCO_2$ and 500 $GtCO_2$, respectively (Intergovernmental Panel on Climate Change, 2021, Table SPM.2, SPM-38). The whole range of values are subject to an additional increase or decrease of 220 $GtCO_2$ or more, depending on variations in reductions in non-CO_2 emissions (Intergovernmental Panel on Climate Change, 2021, Table SPM.2, SPM-38). The historical cumulative emissions from 1850 to 2019 are estimated at 2390 ± 240 $GtCO_2$ (Intergovernmental Panel on Climate Change, 2021; Table SPM.2, SPM-38). In other words, the total carbon budget had been reduced by 2390 ± 240 $GtCO_2$ by the end of 2019.

From an economics perspective, at the heart of the problem lies the concept of efficient level of emissions, which economists define as the level at which the social cost of the last tonne of CO_2 emitted is equal to the social benefit. This efficient level of emissions does not exist in the science of climate change, which is now estimating remaining budgets that will run out, implying that emissions need to reach net-zero and stay at net-zero (Rogelj et al., 2019) by mid-century (Intergovernmental Panel of Climate Change, 2018, p. 12).

5. Switching caps and switching prices

Since the SCC measures the cost of emitting an additional tonne of CO_2 or its equivalent into the atmosphere, it evaluates only small changes in emissions and is therefore "ill-suited" to guide "policies aimed at broader targets", such as achieving net-zero emissions by a certain date (Wagner et al., 2021, p. 550). To combat climate change, marginal analysis may have had a place back in the 1990s and if governments had implemented efficient carbon prices based on the SCC back then, the level of emissions today would probably be lower, or even zero, due to new technologies taking off. That did not happen, and the longer we take to act, the higher the difficulty and cost to reduce emissions will be (United Nations Environment Programme, 2019). With an objective of net-zero, marginal analysis can inform but cannot lead decision making. The "potential of carbon pricing is still largely untapped, with most carbon prices below the levels needed to drive significant decarbonization" (World Bank, 2021b, p. 8).

In 2009, the UK government moved away from the SCC, and started valuing non-traded carbon (i.e., emissions not traded under the EU ETS) on the basis of estimates of the abatement costs that will need to be incurred in order to meet specific targets (Department of Energy and Climate Change, 2009).[6] I propose we go a step further. Nationally determined contributions, which we know quite well are not enough to achieve the reductions required at planet-level (United Nations Environment Programme, 2019; Watson et al., 2019; World Bank, 2021b), need to be delivered with consistent policy that sends the right signals. The question should therefore be what combination of taxes (or caps)

[6] Until 2021, the UK took part in the EU ETS but on 1 January 2021, a UK Emissions Trading Scheme (UK ETS) replaced the UK's participation in the EU ETS (Department for Business, Energy & Industrial Strategy, 2021a). The UK ETS is of the same scope as the EU ETS but the schemes are not linked. Because some emissions are covered by trading and some are not, and these have separate emission reduction targets, the UK government treats emissions in the two sectors as different commodities and values them differently: CO_2e emissions in the traded sector are valued at the Traded Price of Carbon, whereas CO_2e emissions in the non-traded sector are valued at the Non-Traded Price of Carbon (Department for Business, Energy & Industrial Strategy, 2021b). The traded and non-traded carbon prices have always been different but are projected to converge and be equal from 2030 onwards (Department for Business, Energy & Industrial Strategy, 2021b).

and subsidies, and other policies, can a government implement to make clean technologies relatively cheaper and more attractive than dirty ones. This is essentially what the High-Level Commission on Carbon Prices (2017) calls "switching prices". These would need to be set at national, or even sub-national, level, or ideally, granulated down to specific industries. An alternative would be to implement switching caps instead. These would need to be progressively binding, country- and sector-specific, and consistent with emission reduction targets. Switching caps would yield permit prices that would build up to the sector-specific switching price. Both approaches, sector-specific switching prices or switching caps, would be difficult from a political economy perspective, potentially more difficult than a uniform carbon tax or cap, but given the urgency of the problem, the difficulties may not be insurmountable, provided there is strong political will.

Fig. 1 shows that in 2018 GHG emissions originating in the European Union were 21.7% lower than in 1990. However, emissions originating in China and India were 283% and 175% higher, respectively. In the US, they were just over 1% higher, although from 1997 to 2008 they were much higher (up to 15% higher). The US, China and India hold 80% of the low-cost mitigation opportunities across G20 countries (Parry, 2019, p. 19), and the carbon price or cap needed would not be as stringent as that required in, for example, the EU.

Having a homogeneous carbon price or cap has the attraction that abatement takes place where it is cheapest. Those sectors of the economy where it is cheaper to pay a tax or buy a permit do not abate or abate less. This attraction is the very problem of such an approach, which stimulates "a search for low-hanging fruit", something that was important back in the 1990s but that can now jeopardize climate action, as "we must eventually pick all of the apples on the tree" (Patt and Lilliestam, 2018, p. 2497). The exception is that of specific sectors, such as for example, the aviation sector, which still heavily relies on petroleum-based fuels, and will need to be dealt with in other ways, such as using Carbon Capture and Storage or Carbon Capture and Utilization (Becattini et al., 2021). Since long-haul flights do not have close clean substitutes, it would not be possible to have a "switching" price or cap, as there is no alternative mode of transport or fuel to switch to.

Although the cost of wind and solar have been cost-competitive with coal, gas, and nuclear generation for a number of years, and the cost of renewable energy continues to fall (Lazard, 2019), most renewables remain expensive relative to fossil fuel-based electricity (Banet et al., 2021). This also applies to the cost of batteries and electric vehicles, which continue to fall but they are still relatively more expensive (Santos and Rembalski, 2021; Banet et al., 2021). The relative costs of wind and solar energy, biomethane, hydrogen related technology, and alternative fuel vehicles are still dependent on R&D and policy support (Pollitt and Chyong, 2021, p. 37).

Unless relative costs change, and the lock-in by institutional and infrastructure factors is lifted, it will not be possible to decarbonize the economy. The relative cost of clean technologies will decrease, thanks to the effects of learning and economies of scale (High-Level Commission on Carbon Prices, 2017, p. 29) even without any government intervention. The problem is that to limit global warming to 1.5 °C, we need to reach net-zero by mid-century (Intergovernmental Panel on Climate Change, 2018, p. 12), and we cannot afford to wait until relative costs eventually come down. Against a framework where different countries are at very different stages in their transition to low carbon, switching prices and switching caps may be the only instrument capable of enabling countries to meet their Paris pledges.

Subsidies, regulations and other supportive policies such as public investment in green infrastructure and R&D of clean technologies, should be implemented alongside (High-Level Commission on Carbon Prices, 2017; Tvinnereim and Mehling, 2018; Gaspar and Parry, 2021), to accelerate socio-technical transitions and facilitate the diffusion of clean technologies (Geels et al., 2017; Patt and Lilliestam, 2018), helping to ease the restrictions caused by institutions and infrastructure. These complementary policies are essential because they can "target emissions reductions with very high abatement costs" (World Bank, 2021b, p. 9) and because "feasible carbon prices are unlikely to deliver the change required on the necessary timescales" (Hepburn et al., 2020, p. 1). In other words, when switching prices (or equivalent caps) are unacceptably high (low) to be implemented, complementary policies are especially needed. As clean technologies mature and replace dirty technologies and factors of production are reallocated, many of these prices, caps, subsidies and complementary policies will no longer be needed.

Given the heterogeneity of the required switching prices and switching caps across sectors and countries, border adjustments may be needed. These are important when production can move away from the country/area where the policy applies or when domestic producers are vulnerable to leakage from imports (Bushnell and Chen, 2012, p. 648). In fact, some countries and regions with aggressive carbon pricing are considering the implementation of carbon taxes on imports from countries without similar policies (Gaspar and Parry, 2021).

Switching carbon prices or switching caps should be calculated and implemented across all sectors and technologies which have a more expensive low or zero carbon alternative. They would also need to vary over time, in order to reduce demand for dirty technologies progressively, and not suddenly, and thus prevent untold disruption and support a just transition, discussed in the following section.

6. Just transition

In the 1990s, trade unions in North America started to highlight the concept of just transition, understood as (government) support for workers who had lost their jobs as a result of policy interventions aimed at protecting the environment (Smith, 2017, p. 2). As highlighted above, decarbonizing the economy will result in a reallocation of factors of production, and this will have important political implications. A reallocation of factors of production away from carbon intensive sectors will need to be supported by governments or otherwise it could be very costly on jobs and families. Government support could include, for example, job creation in green sectors and compensation for workers affected by the transition to a low-carbon economy (Healy and Barry, 2017, p. 455). In reality, the concept of a just transition has grown and it now encompasses not just issues related to the potential impact on carbon intensive sector workers but also issues related to "environmentally and socially sustainable jobs, sectors and economies" (Smith, 2017, p. 3), and all that they entail: zero waste, regionalized food systems, community-based renewable energy (Healy and Barry, 2017, p. 454–455), to name but a few.

Trade union organizations even managed to get the concept of just transition in the preamble of the Paris Agreement (Smith, 2017, p. 3): "the imperative of a just transition of the workforce and the creation of decent work and quality jobs" (United Nations, 2015). Revenues from carbon pricing can be used to support a just transition by, for example, investing in areas where populations have been affected by climate change or abatement measures (Carbon Pricing Leadership Coalition, 2021, p. 13) and assisting vulnerable households and workers (Gaspar and Parry, 2021). Workers could be supported with retraining and relocation (Healy and Barry, 2017, p. 457). Ideally, these interventions should take place before disruption starts (Healy and Barry, 2017, p. 457).

Whether carbon pricing will take the form of uniform prices and caps, or switching prices and caps, may not make much difference in the matters needing attention for a Just Transition, but the speed with which the Transition occurs will. This problem, however, falls outside the remit of the present paper.

7. Conclusions

Three widely agreed upon and demonstrated principles of environmental economics are the internalization of marginal external costs, whether through price or quantity controls or a combination of both, careful instrument design to avoid double charging, and emissions reduction where it is cheaper first. The first two principles are not applicable to climate change any longer. Not only do we need switching carbon prices or switching caps on dirty technologies and subsidies to clean technologies, but we also need complementary policies, such as regulations, and government investment in clean infrastructure and R&D. The third principle, i.e., reducing emissions where it is cheaper first, is becoming problematic because time is running out. In the very short term, the idea makes sense, but not for much longer. After decades of reducing emissions where it was cheaper, the time has come to reduce emissions in all sectors which have low or zero carbon alternatives, even in those where these are still relatively expensive.

Climate change policy in general and carbon pricing (including cap-and-trade and subsidies to clean technologies) in particular should be consistent with reduction targets, as dictated by the science. At present, the gap is so large that there is no risk of over-abating. Furthermore, there is widespread agreement that on top of the climate benefits from a reduction in CO_2 emissions there are many non-trivial co-benefits, including reductions in deaths from air pollution (Rao et al., 2016; High-Level Commission on Carbon Prices, 2017; United Nations Environment Programme, 2019; Parry, 2019). The time is ripe to act with the urgency we have not shown yet.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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