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PERSPECTIVE

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Making carbon pricing work for citizens

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The gap between actual carbon prices and those required to achieve ambitious climate change mitigation could be closed by enhancing the public acceptability of carbon pricing through appropriate use of the revenues raised. In this Perspective, we synthesize findings regarding the optimal use of carbon revenues from both traditional economic analyses and studies in behavioural and political science that are focused on public acceptability. We then compare real-world carbon pricing regimes with theoretical insights on distributional fairness, revenue salience, political trust and policy stability. We argue that traditional economic lessons on efficiency and equity are subsidiary to the primary challenge of garnering greater political acceptability and make recommendations for enhancing political support through appropriate revenue uses in different economic and political circumstances.

Economic analyses have long recommended carbon pricing as an indispensable strategy for efficiently reducing GHG emissions and tackling climate change. After set-backs over the past two decades, carbon pricing has become popular once again. Today there are more than 70 national or subnational initiatives that now generate over US$30 billion in revenue annually[1]. Since 2016, eight new carbon-pricing initiatives have been implemented[2], with dozens of additional countries having pledged under the Paris Agreement to consider implementing carbon pricing in the years ahead.

The popularization of carbon pricing has been spear-headed partially by the Carbon Pricing Leadership Coalition (https://www.carbonpricingleadership.org). Its High-Level Commission on Carbon Prices — of which one of our authors is co-chair and another is a commission member — recently concluded that achieving the goals of the Paris Agreement requires a carbon price of US$40–80 per ton of CO_2 (tCO_2) by 2020, rising to US$50–100 tCO_2^{-1} by 2030 (when combined appropriately with other policies)[3]. With only 20% of global GHG emissions covered by a carbon price at present, and most existing prices below US$40 tCO_2^{-1}, expanding coverage and raising prices could generate substantial additional public revenues that may serve as a means to increase public support for carbon pricing.

Several proposals have been advanced, with the primary goal of increasing acceptability. California and Massachusetts are currently considering carbon pricing proposals with revenues mostly recycled as per-capita dividends[4,5]. The US Climate Leadership Council has proposed a national carbon tax with revenues recycled to citizens as monthly dividends[6]. These proposals are in line with recent lessons on the acceptability of carbon pricing from studies in behavioural economics and political science, collated and reviewed here.

The reviewed works strongly emphasize the importance of distributional fairness, revenue salience, political trust and policy stability amid partisan changes in government. Uniform or targeted transfers to citizens can address these concerns, as can mixed packages that include green spending. Although revenue uses such as green spending, tax cuts or directed transfers are appropriately used in different national contexts, our findings suggest that lump-sum dividends are more stable over time, particularly in countries that are bogged down with issues of economic inequality, political distrust and polarization. If the benefits of these approaches are clearly communicated to the public, they might outperform other mechanisms in terms of acceptability.

This study is motivated by two observations. First, insights on revenue recycling from behavioural economics and political science are scattered across different literature strands and are underappreciated in traditional economic settings. Second, most reviews on this topic are limited to one or two fields of study, and rarely provide the full picture[7–10]. We complement previous studies on public support for climate policy[8] and optimal revenue recycling[9,10] by reviewing more recent behavioural and political science findings. Comparing these insights with traditional equity and efficiency considerations, we provide an ordinal classification of different recycling options by their impacts on acceptability, equity and efficiency. We discuss how this classification and its policy implications align with real-world carbon-pricing regimes.

We focus on making carbon pricing popular for citizens by recycling revenues, so only briefly discuss industry concerns about competitiveness and carbon leakage[11–15]. While most companies can adapt and innovate in response to a carbon price, certain emissions-intensive, trade-exposed industries may require government assistance[12]. Many countries with a carbon price have granted emissions-intensive, trade-exposed sectors tax exemptions or free allocations that weaken the price signal and produce windfall profits for a few large companies[16]. There are trade-offs between the carbon revenue uses that are most popular with citizens and those that narrowly compensate emissions-intensive companies. The focus of some governments on the latter is understandable, given that emissions-intensive industries tend to be more politically active in opposing carbon pricing than others are in supporting it[17]. Nevertheless, we show that strategic revenue recycling may create

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new powerful constituencies with strong economic incentives to support carbon pricing; the competitiveness concerns of emissions-intensive industries could instead be more productively addressed through other means, such as tariffs on imports of highly traded emission-intensive commodities[18], for example. As carbon prices spread, concerns about competitiveness should subside, and losses in fossil fuel-based production may be counterbalanced by gains in growing low-carbon sectors[19].

After reviewing lessons about public preferences on carbon pricing and preferable forms of revenue recycling from the theoretical literature in public economics, behavioural and political science, we provide an ordinal ranking of options with an accompanying decision-tree diagram based on the criteria of efficiency, equity and public acceptability, followed by a review of several real-world carbon pricing regimes. We conclude with a brief discussion of the prospects for incorporating these lessons in ongoing and upcoming carbon-pricing proposals.

Advances in public economics of carbon pricing

Lessons about equity and efficiency from traditional economic analyses are of little value if carbon pricing cannot be implemented. Nevertheless, such lessons matter in a fundamental sense — for good policy design — and because they also influence the acceptability of a carbon price. We therefore start with insights from small theoretical models that precisely identify specific effects, and large numerical models that yield quantitative insight into policies in specific countries.

First, a large body of literature has examined the influence of tax constraints in the context of environmental taxation on the design of carbon tax reforms. It builds on the idea that a (weak) double dividend arises when using carbon price revenues for cutting distortionary taxes[20]. For example, it has been found that uniform lump-sum recycling is preferable to linear income tax cuts from the point of view of enhancing equity[21]. Moreover, real-world governments face informational and political constraints, pre-existing distortionary taxes and resistance of special interest groups[22,23]. As a consequence, such analyses will almost always be 'second best', in that the optimal carbon tax reform is assessed when crucial information or policy options are unavailable. In the context of this Perspective, we usually refer to this second-best concept of optimality.

The constraint generally believed to be most relevant for deriving optimal income taxes is the unobservability of individual households' skill levels and the consequential indeterminacy of individualized lump-sum transfers to households[24]. Despite this constraint, economic analyses of environmental taxes typically assume that the tax system is optimal, given that other imperfections could be addressed directly rather than taking them into account when designing environmental taxes. Based on these assumptions, recent research assesses optimal nonlinear labour taxes in the presence of an environmental externality[25–28]. One important conclusion from this literature is that income tax cuts are not necessarily more efficient than uniform lump-sum transfers[28,29]. This result is a consequence of the (unrealistic) assumption that all taxes are already optimally set: the labour tax redistributes optimally between households and generates revenue, and additional revenue can be redistributed through non-distortionary uniform lump-sum transfers. In such a setting, recycling carbon tax revenue by cutting taxes is distortionary and uniform lump-sum recycling is the preferred option. If, instead, the labour tax system is suboptimal, a comprehensive tax reform is potentially desirable as the carbon tax revenue can be used to move the tax system closer to its optimum, thus enhancing both equity and efficiency[29]. Further, if the economy is distorted in the sense that shadow and market prices do not coincide, lump-sum transfers can also be distortionary[30]. In practice, tax systems are not optimal, thus it is more policy-relevant to identify ways in which carbon pricing can help to reduce inefficiencies in the tax system[31].

Second, larger models can combine micro- and macro-economic analysis using large datasets and significant computational power to provide quantitative assessments of the equity and efficiency impacts of different revenue recycling mechanisms. There are three main messages from such modelling (see Supplementary Information Part I)[32–37]. First, almost all studies agree that recycling the revenue through capital or corporate tax cuts is preferable, from an efficiency perspective, in the long term (based on particular assumptions about incentive effects of corporate taxation; results are sensitive to these assumptions). Labour tax reductions are less efficient, whereas directed and uniform transfers perform worst in terms of efficiency. Second, regarding short-term effects on income and consumption, studies disagree about which recycling mechanism performs best. One study[35] finds that uniform lump-sum transfers are superior to other recycling mechanisms in the short-term, but others do not[33,34,36,37]. Third, with respect to distributional impacts, directed transfers are most equitable, followed by uniform transfers, labour tax cuts and capital tax cuts. Such models also consider options that are not fiscally-neutral — where net revenue from the carbon tax is raised — such as public deficit-reduction[32,38] and pension funding[33,39] (see Supplementary Information Part II for a more detailed discussion). One shortcoming of this literature is that nonlinear labour tax reductions are usually not considered, because a mechanism for determining an incentive-compatible income tax system is missing. Hence, these results are complementary to those obtained by the methods of optimal taxation.

In sum, traditional equity- and efficiency-focused models demonstrate that, if the initial tax system is suboptimal, moving it closer to the optimum takes precedence. In the case of labour taxes this can enhance both equity and efficiency. There might be a trade-off, however: the recycling mechanisms considered most efficient by a majority of the numerical models (capital/corporate tax reductions) tend to be the least equitable, whereas the most equitable (directed transfers to households) are considered least efficient. Uniform lump-sum recycling outperforms labour income tax cuts in terms of both equity and efficiency only when the initial tax system is close to the optimum.

Behavioural constraints on carbon pricing

Behavioural economic research has shown that the assumption that households make 'rational choices' is often contradicted in practice, and is sometimes an inadequate basis for policy analysis[40–42]. A nascent literature has begun to apply insights from behavioural economics to the use of carbon-pricing revenues. In general, behavioural economics raises the important question of whether corrective environmental taxation should be complemented by additional instruments that target behavioural biases[43,44]. This section focuses specifically on how behavioural effects can constructively reorient debates about the design of carbon-pricing instruments with a view towards public acceptability. Behavioural economics, when analysing choices about consumption options, classifies behavioural effects by whether they alter the preference, the belief or the decision-making process of an individual[42]. Here we systematize the behavioural effects as factors that may alter hypothetical choices over policy options. These effects can similarly alter citizens' preferences, beliefs or decision-making regarding different carbon pricing reforms. We consider preferences over policy as only changing on longer timescales, whereas beliefs and decision-making processes about policy may be more malleable — that is, they relate to citizens that do not have fundamental pre-existing climate policy preferences, but might be more readily influenced by new information or by the specific policy design. From the studies reviewed, four effects emerge.

The first effect is that the public's willingness to pay a given carbon price is a function of political, economic and cultural beliefs. Using discrete choice experiments, one study[45] estimates that Italians are

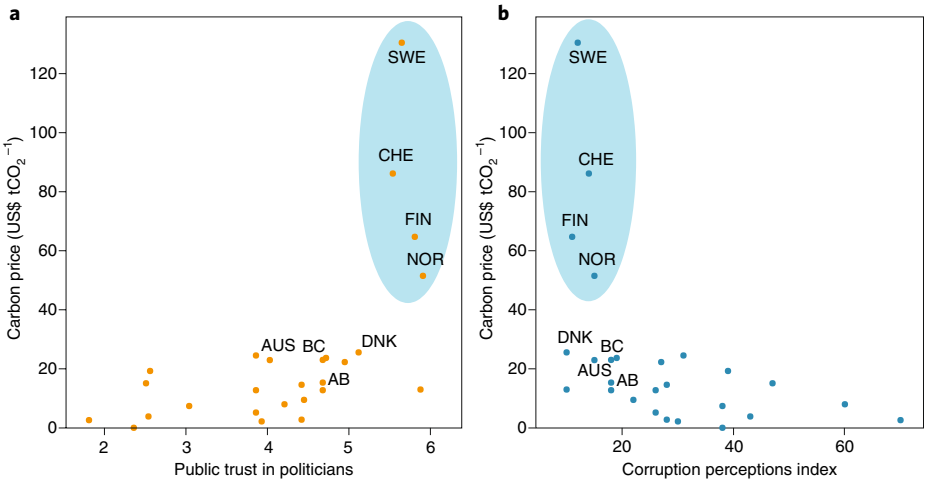

Fig. 1 | Carbon prices, trust and corruption. a,**b**, Carbon prices in selected countries are plotted against levels of public trust in politicians (**a**) and perceptions of corruption (**b**). Carbon price data are from ref. [91], public trust data from ref. [92] and corruption data from ref. [93]. All data are for 2016, except those for Australia, which are for 2012 (due to later carbon tax repeal). Carbon rates for EU countries are unilateral, excluding the EU ETS price. The corruption perceptions index is converted so that higher values equal greater corruption. Countries are labelled by ISO country codes, except for Canadian provinces. AB, Alberta; BC, British Columbia. Blue ovals highlight countries with a carbon price above US$40 tCO_2^{-1}.

willing to pay €133–164 tCO_2^{-1} avoided, while Czechs are willing to pay €94 tCO_2^{-1}. Another study[46] finds that a greater willingness to pay a carbon price in Germany and China is correlated with higher educational attainment and left–green partisan proclivities, whereas in the United States only partisan affiliation matters — and to a considerably greater extent. Politically motivated opposition to carbon pricing in the United States resembles what some authors call "solution aversion"[47]: the tendency for citizens to be more skeptical of environmental problems whose policy solutions contradict or challenge their underlying ideological predisposition. Conservatives, not liberals, consider taxes less preferable than subsidies. This finding is confirmed by other researchers[48], who identify correlations between different worldviews and skepticism towards climate risk. According to one paper[49], the division between so-called egalitarian–communitarian and hierarchical–individualistic worldviews explains a great deal of public disagreement over environmental policy. Hence, from an acceptability perspective, policymakers should avoid triggering solution aversion when designing revenue recycling mechanisms.

The second effect concerns ignorance of the Pigouvian effect of carbon pricing together with the argument for earmarking the revenues to compensate for this effect. Conducting a single-price market experiment, the researchers involved found that citizens often ignore the possibility of an environmental tax itself causing a shift in behaviour, and focus instead on the potential to effect change with the revenues raised[50]. When carbon revenues go towards the general government budget, some studies have found that public acceptability is lower[51–54]. If instead carbon revenues are earmarked for a specific purpose — notably as targeted green investments or transfers to particularly affected groups — citizens report greater acceptability of carbon pricing[50,52,53,55–57]. In Turkey, recycling preferences seem to depend on socioeconomic status[58].

The third effect concerns the labelling of the carbon price. Tax aversion is a prevalent feature of fiscal policy, and carbon pricing is no exception. There is some consensus that overcoming tax aversion is at least partly a matter of how the measure is labelled. One study[50] shows that relabelling an environmental tax as a 'fee' made it more popular, particularly when revenues were returned to citizens as uniform lump-sum payments; that is, 'fee and dividend'. Using survey data, another study[53] also finds that relabelling the tax by a different name (for example, a 'climate contribution') increases public acceptability. See also section 4.4 in Drews and van den Bergh[8].

The fourth effect concerns the salience of the revenue recycling mechanism. A survey study on the acceptability of different revenue recycling mechanisms in Switzerland concludes that uniform lump-sum transfers are favoured over other mechanisms in part due to their high visibility and their progressive effect[59]. These results were dependent on a good communication strategy that explained the distributional consequences to consumers, which in turn enhanced the salience[60]. Other researchers[61] confirm that clear communication of the benefits and compensation of households through salient (uniform) transfers are crucial for successful fossil fuel subsidy reforms (see below). A related effect concerns the salience of (the environmental benefits of) the tax: it has been shown that British Columbia's carbon tax caused a reduction in short-term gasoline demand that was 4.1 times stronger than the demand reaction caused by a similar price increase through other factors[62]. These findings reflect earlier results regarding the salience of sales taxes[41] and the question of how gasoline demand is impacted differently by price changes and gasoline tax changes that are not framed as a carbon tax[63–65].

Several recycling mechanisms can address one or more of the aforementioned behavioural effects, notably uniform or directed transfers and green spending, depending on the specific circumstances. For instance, having a large gap in infrastructure financing could justify using carbon-pricing revenue for investment in (green) infrastructure[66,67]. Directed or uniform transfers to citizens would benefit most poor households by allotting more in transfers than they spend on taxes. These transfers could be very salient if paid directly to the households at regular intervals. Further, if budget-neutral, uniform lump-sum recycling would be consistent with more centre–right worldviews as it would not increase the size of the government.

Conclusions regarding the acceptability of uniform lump-sum transfers differ depending on the underlying study design: survey evidence from Switzerland shows that uniform lump-sum transfers are more acceptable than tax reductions (if participants are aware of the progressivity of uniform transfers)[59]. By contrast, laboratory experiments provide arguments for targeted transfers[50]. In these experiments, uniform transfers are seen to lead to the most unequal

Table 1 | Recycling mechanisms ranked according to efficiency, equity and acceptability

Recycling mechanism	Efficiency	Equity	Acceptability
Labour tax (initial system non-optimal)	+	+	0
Labour tax (initial system optimal)	0	0	0
Capital/corporate tax (initial system non-optimal)	+	−	0
Capital/corporate tax (initial system optimal)	0	−	0
Directed transfers	0	+	+
Uniform transfers (initial system non-optimal)	0	+	+
Uniform transfers (initials system optimal)	+	+	+

Equity and efficiency are determinants of acceptability, but the evaluation of acceptability focuses on the other factors that determine it. We use the definition of optimal as given in the section on public economics. Plus (+) and minus (−) signs indicate positive and negative evaluations, respectively, whereas 0 indicates a neutral evaluation.

outcome as they do not account for rich households that pay more carbon taxes in absolute terms, which would make the net distributional effect of uniform lump-sum recycling progressive. More research is required on whether lump-sum dividends are perceived as egalitarian or not: on the one hand, the recent popularity of 'universal basic income' proposals may lead to the conclusion that lump-sum dividends are seen as egalitarian[68]. On the other hand, they might be seen as unnecessarily giving out money to the rich.

Political trust and lasting political constituencies

Several recent studies in political science complement the findings from behavioural science. There are two major lessons relevant to carbon pricing and revenue allocation.

The first is related to political trust: countries with greater public distrust of politicians and perceived corruption have been robustly associated with weaker climate policies and higher GHG emissions, when relevant political and economic factors are taken into account[52,69]. One study[69] shows that crises of confidence in government weaken the legislature's mandate to enact foresighted, cost-imposing climate policies and strengthen the relative influence of businesses opposed to regulatory agendas. Other authors similarly find that higher trust in politicians is positively associated with support for carbon taxation in Sweden[70]. Figure 1 shows that the only countries with a carbon price above US$40 tCO_2^{-1} are relatively high-trust and low-corruption (although such analyses of course provide no evidence of causality). These studies suggest that carbon revenues should be allocated so as to minimize further grounds for political distrust, and ideally to reinforce greater confidence in government. High-trust states tend to be more responsive to the preferences of citizens across the political spectrum and deliver relatively more egalitarian socio-economic outcomes[71,72]; therefore, in countries with low levels of political trust, the introduction of a carbon price may be more probable and popular if revenues were put towards uniform lump-sum or directed transfers. Their salience to the average household may reinforce perceptions of government responsiveness. But political trust could also be promoted through efficient and equitable tax swaps that take the various issues of tax reform in globalized economies out of their various separate compartments[73]. For instance, in Sweden, the public's acceptance of a broad reform of the fiscal system was enhanced by a process of social deliberation and dialogue[74,75]. Such a comprehensive approach may have promoted trust and laid the foundation for the gradual rise of the carbon price (from €27 tCO_2^{-1} in 1991 to €123 tCO_2^{-1} in 2017).

The second lesson concerns the importance of concentrating the benefits of carbon pricing reform on constituencies that are likely to actively support the policy's passage and preservation. Olson argues that a policy reform is more likely to be enacted if the costs are diffuse and the benefits are concentrated[76]. The challenge with carbon pricing is that it tends to have diffuse benefits and concentrated costs, such that the scattered beneficiaries of the policy are less likely to support it in the political process than carbon-intensive companies are to oppose it. The lesson, then, relates to the fourth behavioural effect: to make the benefits more salient to small, but politically important, groups. This could suggest revenue recycling via targeted transfers to, for example, coal mining communities to make the costs less concentrated; but it could also entail targeted transfers to clean energy companies or uniform transfers to households, to create beneficiaries with strong economic incentives

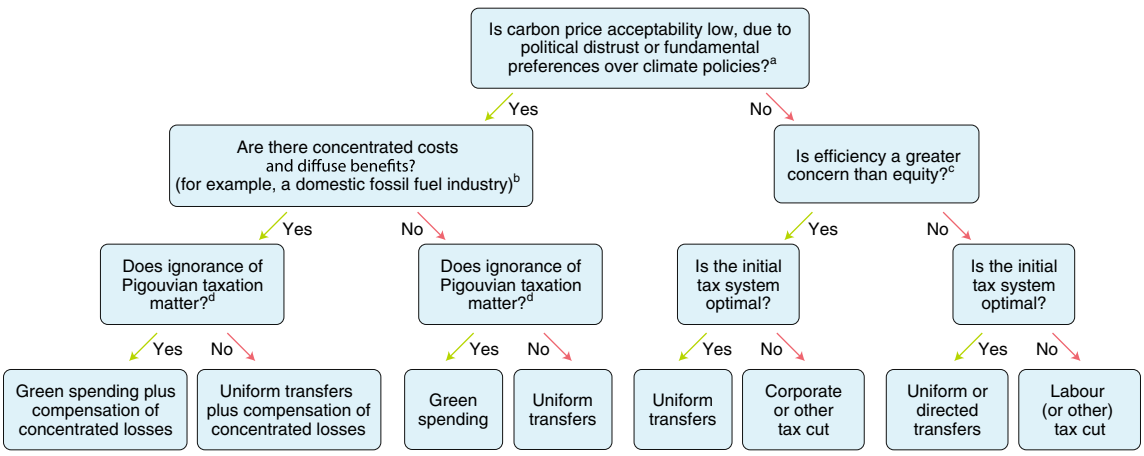

Fig. 2 | Decision-tree diagram for carbon revenue recycling. This decision tree summarizes the findings from the reviewed studies. If acceptability of carbon pricing is high (right branch), lessons from traditional public economics are more applicable. If acceptability is low (left branch) lessons from behavioural and political sciences predominantly apply. [a]Lessons regarding political trust and political, economic and cultural world views apply. [b]Lessons regarding the salience of revenue recycling and the creation of politically powerful beneficiaries apply. [c]From this node traditional public economics lessons apply. [d]Lessons on citizens' ignorance of the corrective (Pigouvian) effect of carbon pricing apply.

to support the policy's enactment[77]. More recently, laboratory experiments[50] corroborate Olson's hypothesis for the case of a carbon pricing reform, suggesting the popularity of targeted transfers. But ultimately, winning over sufficient parliamentary support may require a strategic mix of revenue uses, depending on legislative institutional design, party strength and the particular political cycle — as the literature on 'pork-barrel spending' has indicated[78,79].

The second lesson also applies to policy preservation amid successive partisan changes in government. Several studies show that intertemporal considerations lead parties to create path-dependent policies, including revenue earmarking commitments, that mitigate the risks of backsliding under future parliaments[80–82]. The carbon price is more likely to survive successive partisan changes in government if it benefits constituencies across the political spectrum. This could be achieved by concentrating benefits on small but diverse and influential groups, but it could also involve recycling revenues to the largest possible proportion of the population. With this in mind, there is reason to think that uniform lump-sum transfers may be more stable and resilient than targeted transfers. Rothstein concludes that "the "poor," the "underprivileged," […] or similar social groups are too small to constitute a sufficient electoral base for a comprehensive universal welfare policy"[83]. The universality of Social Security and Medicare in the United States, for example, has largely safeguarded these programmes from multiple rollback attempts[84]. Further, very few people — not even the poorest citizens — want to think of themselves as poor and therefore needful of government assistance[85], which may make equal per-capita dividends more popular.

These two lessons from the political science literature on the importance of political trust and creating lasting political constituencies that support carbon pricing complement the behavioural studies pointing to the popularity of either targeted or uniform lump-sum transfers.

Ranking of the recycling mechanisms

Table 1 summarizes the insights from the previous sections by rating recycling mechanisms along three dimensions: acceptability, equity and efficiency.

The perceived equity and efficiency of options is a determinant of acceptability, insofar as citizens have preferences over climate policies being efficient or equitable[8]. The ranking is somewhat crude, as it does not account for specific economic circumstances. Nevertheless it demonstrates that uniform lump-sum recycling performs well in all three categories, provided that the initial tax system is close to optimal. Otherwise, uniform transfers, directed transfers and labour tax cuts fare equally well, but in different categories: although transfers fail to capture the opportunity to correct distortions in the tax system, they have the compensating attraction of being politically appealing. Finally, it is worth remembering that carbon tax revenues need not be used for one purpose alone; in practice, as the next section demonstrates, policymakers have selected a combination of approaches.

To make these rankings more decision-oriented and to account for varied economic and socio-political circumstances cross-nationally, we present a decision-tree diagram (Fig. 2). Consistent with our view that, for effectiveness in delivering results, acceptability should take primacy over concerns about efficiency and equity, the diagram begins with the first-order question: are behavioural and political factors preventing carbon price reform?

The diagram illustrates that when political distrust or preferences over climate policies are major obstacles, green spending or uniform lump-sum transfers are preferable, in terms of the likelihood of policy impact, but might need to be combined with targeted transfers to actors who are particularly affected. If, by contrast, citizens are generally more willing to pay for climate mitigation and the government is not caught in the corruption–distrust trap, policymakers will have greater flexibility with privileging either equity or efficiency.

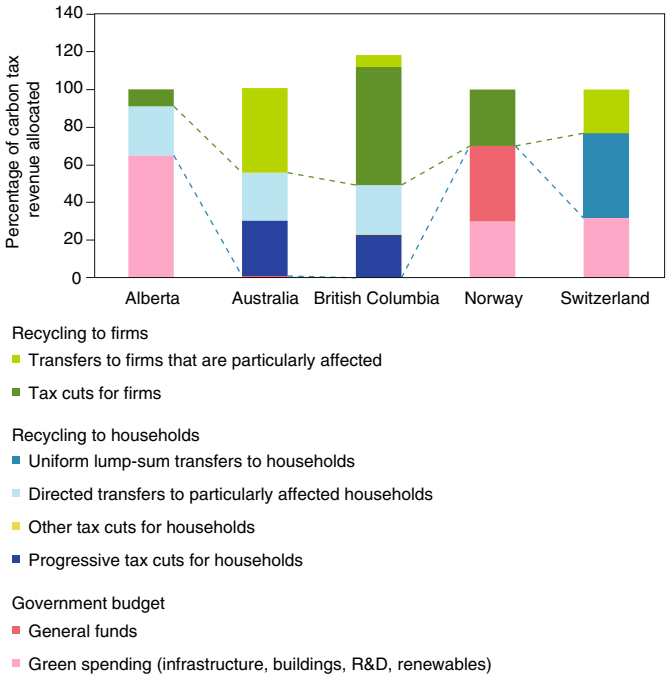

Fig. 3 | Real-world revenue recycling. Comparison of the revenue-recycling options of five carbon tax schemes. Data from refs [94–99]. The numbers used for Norway are estimates by Carl and Fedor[98] based on incomplete data. Note that British Columbia committed to additional spending, independent of the raised revenue; the spending therefore exceeds 100%. The carbon tax levels in the different regions are as follows: Alberta, US$24 (2018); Australia US$23 (2012–2014); British Columbia US$24 (since 2012); Norway US$4–56 (2017, depending on fuel type and usage); Switzerland US$87 (2017).

Real-world experience with carbon revenues

In this section, we review real-world experiences with carbon pricing reforms, including both price and quantity instruments as well as the removal of fossil fuel subsidies. Policymakers seem to have adopted, consciously or unconsciously, many of the recommendations from the aforementioned behavioural and political studies, particularly regarding the advantages of earmarking revenues, ensuring salience and their perceived distributional fairness.

Revenues from real-world carbon-pricing schemes are rarely recycled in any single way. Extant schemes typically incorporate multiple uses of revenues — from recycling to households to compensate for higher energy prices, to recycling to firms to address competitiveness concerns, to contributing to general government or clean energy budgets. In the following, we consider carbon taxes, emissions trading schemes (ETS) and fossil fuel subsidy removal separately.

Figure 3 shows how revenues are recycled in five real-world carbon tax schemes. These were selected according to the following three criteria (see also Supplementary Information Part III): (1) carbon price equal to or above US$20 tCO_2^{-1}; (2) the reform has actually been implemented at some point; (3) the available data on revenue recycling is sufficiently detailed (this is usually not the case when the carbon revenue is not clearly assigned to specific recycling options). All analysed schemes return a share of revenues to households as well as to firms, either in the form of transfers or tax reductions, or as a mixture of the two. Additionally, some regions use carbon revenues for green spending — including research and development in green technologies,

Box 1 | Revenue recycling that made carbon pricing work in selected regions

Alberta. More than half of carbon-pricing revenues are allocated to green spending and the price is called a 'levy'[94], in accordance with the behavioural factors surrounding ignorance of Pigouvian taxation and labelling. Combining this with transfers to affected households and firms made the carbon tax politically possible[94].

Australia. Australia has a tortuous relationship with carbon pricing — high stakes and powerful interests have led to political and policy reversals and the defeat of successive prime ministers[100]. A carbon price was, after multiple attempts, introduced by the Gillard Labor government in 2012. It was projected to raise around US$9 billion each year, with roughly US$3 billion recycled to trade-exposed industry, US$1 billion to the power sector and US$5 billion to households[95]. The price was repealed under the Abbott government in 2014, and replaced with a US$2.5 billion subsidy for emissions reductions over four years. Over this period of political instability, public acceptance of carbon pricing remained stable, if finely balanced[101]. The case stands as evidence that a carbon price design that meets equity and efficiency goals is not enough; the politics and political communication is critical. Debates continue in 2018, with a focus on quasi-carbon pricing in the electricity sector.

British Columbia. All revenues are returned to households and firms[102]. The success of its carbon tax reform was facilitated by a surge in public concern about climate change and a right-of-centre government that was backed up by the province's business community. Today, the tax revenue is an important component in the province's budget[102] and public support increased since implementation[103]. Its success reflects lessons on political preferences and salience and highlights the importance of political factors preserving a tax.

Norway. As an economy in which the petroleum industry accounts for a large share of GDP, Norway ensures the acceptability of its pricing scheme to industry through corporate tax cuts. Public acceptance is enhanced by investing in green technologies; the remainder of the revenue is used for the public budget.

Switzerland. The Swiss carbon pricing scheme is also referred to as a CO_2 levy; using one-third of the revenues for green spending and returning the remaining two-thirds to the general public and the private sector. It allocates a substantial share of revenues to households as uniform lump-sum transfers to enhance salience (in 2017, each citizen received a transfer of 67.8 CHF). The successful implementation in 2008 was the result of 15 years of political efforts, popular vote defeats and concessions to industry[104–106].

France. The carbon component of France's consumption taxes will increase from €44.60 tCO_2^{-1} in 2018 to €86.20 tCO_2^{-1} in 2022. In its 2018 finance bill, there are several measures that compensate households for higher energy expenditures — such as transfers to reduce heating costs, subsidies for buying electric cars and tax credits for energy-efficient buildings[107,108] (not shown in Fig. 4).

Sweden. Sweden has the highest carbon price in the world, and directs much of its carbon revenues to the general budget. It is unlikely that this would have been politically possible in a country with greater political distrust[70] (not shown in Fig. 4).

subsidizing renewable energy sources, or public spending on energy efficiency upgrades of buildings. All regions adjust revenue priorities to account for the preferences of special interest groups, which notably includes transfers to energy-intensive firms that are particularly affected by the carbon price.

These similarities aside, there is stark variation in the relative shares of revenues going to firms, households and the general budget. These can be explained by efforts of constituencies to build coalitions for making carbon pricing feasible (see Box 1). High-trust countries such as Sweden and Norway are very likely to have much greater flexibility with respect to possible uses of carbon revenues, as indicated by the choices presented in Fig. 3. This finding is consistent with the conclusions drawn by two studies on the determinants of carbon pricing support in Sweden, and weaker non-market climate policies when political distrust is prevalent[69,70].

In contrast to the carbon tax schemes discussed above, in ETS the revenues — from the EU ETS to subnational systems in the United States and Canada — have been allocated to a greater variety of purposes (including conservation projects, water efficiency projects and transit), but not typically in ways that are salient to taxpayers. It remains to be seen how similar cap-and-trade systems in South Korea and China will allocate the revenues raised. Figure 4 compares recycling in ETS and carbon tax schemes on a global scale. In most ETS, the largest part of the gross revenue is allocated to firms for free via emissions permits for which no payment is required (almost 60% in the EU ETS in 2013)[86], which may be perceived as unfair by the citizens, who might have a sense that rents on the atmosphere belong to all citizens[87,88]. Since it is primarily firms that participate, a great amount of political effort has been put towards granting exemptions or allowances to energy-intensive, trade-exposed firms. In the EU ETS, for example, a small number of firms have received billions of euros per year in windfall profits from selling surplus permits and receiving free allowances[16]. The EU ETS also exhibits persistently low carbon prices[89]. These vulnerabilities of carbon markets have at times drawn considerable condemnation and undermined public confidence in the scheme. Hence, although the negative salience of high carbon taxes may be offset by the salience of lump-sum transfers to households and firms, cap-and-trade systems have largely been unsuccessful at sustaining a rising price through revenue allocation (recent reform proposals in California may be an exception). However, they can initially be designed to transfer value to industry and transition over time to transferring value to citizens: the EU ETS, for instance, continuously increases the share of auctioned allowances over time[86].

Recent initiatives to remove fossil fuel subsidies in India, Iran and Nigeria provide important lessons on how to make these policies acceptable to citizens[61]. As fossil fuel subsidies often favour medium- to high-income households in developing countries (in Nigeria[90], for example) their removal is likely to be progressive. However, this does not mean that poor households are better off in absolute terms. The compensation of poor households that depend on the subsidies is hence a major concern. While the Nigerian initiative to reduce subsidies 2012–2014 had only limited success (most subsidies were reinstated after massive protests, even though they would have been recycled through public investment), the Indian and Iranian initiatives were more fruitful. Both countries ensured the salience of the reforms' benefits through two measures: first, they relied on transparent and abundant information about the reform and about increasing access to banking and identification services (such as Aadhaar in India); second, they compensated

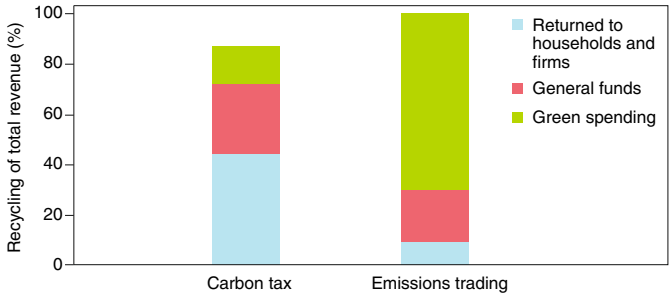

Fig. 4 | Global revenue recycling. Global revenue recycling from emissions trading and carbon taxes (net of free allowances) are compared for 2013. Carbon tax schemes raised around three times more government revenue (US$21.7 billion) than ETS (US$6.57 billion). Shares may not add up to 100% as annual budgeting might not match income flows and categories are not comprehensive. Data from ref. [98].

low- and middle-income households through uniform lump-sum transfers. In Iran, these transfers were substantial, equivalent to 28% of median per-capita expenditures of a family of four in 2011, and lifted millions out of poverty[61].

Conclusions

Carbon pricing initiatives are spreading at an unprecedented rate globally, but the scale and ambition of carbon pricing will need to increase substantially to realize the world's climate targets[3].

Our review of behavioural and political science, public finance and integrated assessment modelling yields four main insights. First, public finance theory generally finds that the revenue from a carbon tax should be used to lower other, distortionary taxes — at least with non-optimal pre-existing tax systems. Second, integrated assessment models usually make the case for mixed recycling through more than one channel, including corporate tax cuts for enhanced productivity. Third, the research in behavioural economics highlights the importance of the salience of the costs and benefits of a carbon tax reform, ignorance of the workings of Pigouvian taxes, labelling of the policy, accounting for different worldviews and earmarking the revenues for a specific purpose. Fourth, studies in political science consider issues of political distrust and the importance of sustaining long-term policies amid successive partisan changes in government.

Real-world recycling schemes differ widely across regions but have two common aspects: first, several important economic actors are compensated; second, some form of transfer exists to compensate those especially hurt by higher carbon prices, such as rural or low-income households. These similarities are largely driven by the effects discussed in the sections on behavioural economics and political science. We therefore conclude that analytical and numerical models that emphasize the efficiency and productivity gains from particular revenue recycling options should serve only as a benchmark, while behavioural considerations aimed at achieving greater political acceptance should take precedence over the perspective of fostering effective action.

The policy implication is that the ideal recycling of carbon pricing revenue strongly depends on the political context: when distributional concerns are the greatest obstacle to higher carbon prices, transfers directed to the poor outperform other recycling mechanisms. When efficiency and competitiveness concerns are the greatest obstacle and trust in the government is high, reimbursing firms through transfers or tax cuts can be superior. Earmarking the revenue for green spending might be the option of choice if the main obstacle is that citizens are unconvinced of the environmental benefits of higher carbon prices. Uniform lump-sum recycling is favourable in more general circumstances, as it may ensure broad public support through its salience and progressivity and due to its properties regarding the stability of carbon pricing policy. This finding aligns with a recent US proposal of a 'fee-and-dividend' approach to carbon pricing[6].

Our findings together help to explain the appeal of current carbon-pricing reform proposals in states such as California and Massachusetts[4,5]. As other states, countries and regions look to enhance the acceptability of carbon-pricing initiatives, there will undoubtedly be additional lessons from these practical experiences to draw on.

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Author contributions

Emmanuel Combet, David Klenert and Linus Mattauch jointly conceived the study. Its design was further refined through inputs from Cameron Hepburn and Ryan Rafaty. David Klenert coordinated the writing process and wrote large parts of the manuscript with inputs from Emmanuel Combet, Cameron Hepburn, Linus Mattauch and Ryan Rafaty. Ryan Rafaty is responsible for writing the section on political science and for creating Fig. 1. David Klenert and Linus Mattauch jointly wrote the behavioral science and public economics sections. Ottmar Edenhofer and Nicholas Stern provided crucial feedback on the manuscript at different stages.

Competing interests

R.R. is employed as a researcher at Climate Leadership Council, a non-governmental organization promoting a proposal for a national US carbon tax with revenues allocated as per-capita lump-sum dividends. This employment commenced five months after he joined as a co-author.

Additional information

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