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Equal tax and equal compensation: A fair and efficient way to save climate

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ABSTRACT

We show that "equal tax and equal compensation" (T&C) is fair as justified by the two fairness principles. It differs from any Pigouvian tax with fixed lump-sum payments and can motivate every country to maximize world welfare. It benefits countries with current per capita emissions lower than the world average and would benefit every country when compared with a fair benchmark where emissions are duly penalized and compensated. Subsidizing emission reduction by poll tax is Pareto efficient and Pareto improving over status quo, but unfair. An imperfect T&C with a sub-optimal tax or pyramid taxes can still benefit the world.

1. Introduction

2023 is the hottest year on record, and the world temperature is likely to rise more than 2°C above its pre-industrialization level by the end of this century. Since climate protection is a public good, countries do not have incentives to reduce GHG emissions to the optimal level and will be trapped into a prisoner's dilemma (Stern, 2006). A binding international agreement is the only effective way to avoid this situation. Unfortunately, the world community has failed to reach such an agreement. The failure is mainly due to lack of public support. Bergquist et al. (2022) show that the most important determinants for public support on climate policy are fairness and effectiveness. This paper proposes a simple solution and shows it is fair, efficient and could gain a majority support in the world.

The proposal is "equal tax and equal compensation" (T&C): a global tax on GHG emission with an equal compensation to the world population. It is based on two principles of fairness: (i) every unit of emission harms climate equally and should be penalized equally; (ii) everyone suffers from global warming almost equally and deserves same compensation.

Although a global carbon tax has been a well-known concept, an equal compensation has not been suggested in COPs and the economics literature. The UN's principle of "*common but differentiated responsibilities*" (CBDR) is too vague to determine each country's specific responsibility. The Kyoto Protocol (1997) did not restrict developing countries' emissions due to their lower per capita emissions and thus failed to reduce the world emission. To obtain universal participation Paris Agreement (2015) relied on "nationally determined contributions" which are insufficient due to the public good nature of climate protection. The Green Climate Fund of $100 billion from 2020, promised since 2010, has not been fulfilled. COP28 last year calls for transition away from fossil fuels in "a just, orderly and equitable manner" to achieve net-zero by or around 2050. However, similar to CBDR, this vague statement does not specify

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any country's obligation and global cooperation which is essential to reach its goal. Without a binding agreement, the world is doomed to fall into a prisoner's dilemma. Even if developed countries reach carbon neutrality within promised dates, the world emission will continue to rise as developing countries will follow their example: to be rich first and then to be clean. To avoid this disaster, we need a binding agreement to motivate all countries, especially developing ones, to set emissions to the optimal levels.

Economists generally agree that an ideal agreement on climate change should satisfy two requirements: 1) efficiency: every participant will choose its emission level to maximize the world welfare; 2) fairness: the result will benefit every country. Unfortunately, no such plan has ever been presented in the literature.

According to the existing economic theory, one solution is a global tax on GHG emission (Nordhaus, 2006 and 2007), with no money transfers across countries. The revenue may be shared equally within each country (Hansen 2009a and 2009b). Without money transfers, developing countries will face disproportionally heavier burdens from the same tax. Weitzman (2017) suggests a World Climate Assembly to set a carbon price based on one-person-one-vote. This will lead to a low price since the majority voters live in developing countries. Nordhaus (2020) suggests that a climate club of developed countries should impose tariffs on carbon contents in their imports from countries unwilling to implement the carbon tax. However, as Barrett (2009) argued earlier, this is difficult in practice and may result in trade wars. Moreover, even if implemented, it will only cover a small part of GHG emissions from developing countries and cannot lead to an optimal outcome.

Following the same economic rationale as a global tax, another solution is a cap-and-trade system (Montgomery, 1972; Tirole, 2008). However, if emission permits are allocated close to current emission levels, they cannot be accepted by developing countries, as they must buy permits from developed countries. For instance, Goodstein and Polasky (2014) consider an equal split of total emission permits between poor and rich countries. As the population ratio between these two groups is roughly five times, their suggestion implies rich countries receive five times permits per capita as poor countries and is apparently unfair. Other ways of permit allocation were proposed by non-economists and will be discussed below.

Similar to carbon taxes (stick), subsidies (carrot) could equivalently encourage emission reductions. Rich countries may subsidize GHG reduction in poor countries (Bradford, 2008; Gersbach, 2008). However, the literature does not specify how much a country should pay or receive. While Chander and Tulkens (1992) suggested that cost sharing should depend on countries' preference for environmental quality, it is difficult to quantify and insufficient as shown by the case of $100 billion Green Climate Fund. However, we will show while a simple subsidization scheme could be Pareto efficient as well as Pareto improving, it turns out to be unfair to poor countries.

In general, the literature on International Environmental Agreement shows that an agreement is very difficult, if not impossible to reach (Wagner, 2001). Hoel (1991) points out that one country's unilateral reduction may increase total emission. Carraro and Siniscalco (1993) and Barrett (1994), Hoel (1992) find that a stable coalition is unlikely to contain many members. Moreover, the membership may decrease if side payments are available (Hoel & Schneider, 1997), though this may not apply given strong country asymmetry (Barrett, 2001, 2005). McKibbin and Wilcoxen (2002) argue that any agreement requiring large transfers across countries will not be accepted by sovereign states. Martimort and Sand-Zantman (2016) show that the optimal actions require incredible threats from committed members. Otherwise, the business-as-usual is the most likely outcome. It seems an international agreement cannot be reached through selfish motivations and must rely on undisputable morale justification.

Outside of "dismal science", non-economists made influential contributions. Tickell (2008) suggests "Kyoto 2″ which sets a global emission cap to prevent the world temperature from rising 2°C. The quota is auctioned out globally, implying an equal right to emit per dollar. While the revenue can be used to support poor countries for climate protection and adaptation, how to allocate the fund is not specified. Meyer (2000) proposes a cap-and-trade system called "Contraction and Convergence". With the same global cap as Kyoto2, emission permits are distributed according to countries' population and to be traded in markets. This system recognizes everyone's equal right for emission and requires countries with high per capita emissions to pay. Unfortunately, since it may suffer from price fluctuation as pointed out by Nordhaus (2009), this brilliant and once popular idea seems to be buried now.

Clearly, if Meyer's idea of equal emission rights is combined with a global tax, instead of a cap-and-trade system, the price fluctuation problem will disappear. Regrettably, such a simple concept has not appeared in the formal literature and only in non-refereed publications. Jin and Kobayashi (2009) argued for "equal tax and equal compensation", though did not provide comprehensive justification presented here. Similarly, Rajan (2019) proposed "a fair and simple way to tax carbon emissions": every country pays (receives) a levy for each of its citizen's carbon emission exceeding (below) the world average per capita emission of 5 tonnes. As the fairness and efficiency are not explicitly justified in his short article,[1] his $10 levy seems to be lower than the optimal level. Recently, Gaspar and Parry (2021) suggest another way to achieve fairness: to impose different tax rates to take into account different economic conditions among developed and developing countries. This would be very difficult to do in practice. Moreover, Pirlot (2021) points out that, this multi-tax system would not obtain the efficiency under a uniform tax. She supports a single tax as most economists do but argues for "the allocation of the revenue of a global carbon tax to developing countries". While this view is consistent with our T&C, the optimal level of the tax and precise way of allocation need to be determined. Moreover, when the optimal single tax is politically infeasible, a multi-tax system similar to but different from Gaspar and Parry (2021) can be useful as will be shown in this paper.

This paper aims to prove T&C's desirable properties of fairness and efficiency. We first show that our T&C proposal differs from previous suggestions, including Pigouvian tax. It is fair and can achieve Pareto efficiency, i.e., maximizing world welfare. It benefits countries whose current per capita emissions are lower than the world average. Although it may not be a Pareto improvement over the

[1] J. Jin provides essential justification for "equal tax and equal compensation" in a letter to Financial Times, https://www.ft.com/content/ea9e99eb-084f-40ee-b667-a63274930c16.

status quo, it is so when compared with a compensated thus fair benchmark. On the contrast, while subsidizing emission reduction by poll tax is Pareto efficient and improving over status quo, it is obviously unfair. We finally show that even a diluted version of our T&C proposal, with a sub-optimal tax or a pyramid tax system, can still benefit the world.

The next section introduces our model. Section 3 explains why Pigouvian tax does not work. Sections 4 and 5 show our T&C is efficient and fair. Sections 6 and 7 argue for its benefit even under a sub-optimal tax rate and a pyramid tax system. Section 8 concludes, and some formal proofs are in the appendix.

2. Model

We assume there are k countries in the world, indexed by i, where $i = 1, 2, \ldots, k$. Country i's population is n_i. Its normal energy consumption, such as oil, coal and deforestation, is represented by GHG emission x_i; its green energy usage, such as hydro, solar and wind power, is y_i; and GHG abatement, e.g., coal treatment and reforestation, is z_i. The net GHG emission is $x_i - z_i$. Green energy contributes to consumption but has no direct effect on emission; while abatement reduces emission but does not contribute to consumption. A representative or average citizen obtains a direct utility from energy consumption, measured by an increasing, twice differentiable and concave function $u_i(x_i + y_i)$.[2] The cost functions associated with x_i, y_i and z_i are all increasing, twice differentiable and convex, denoted by $c_i(x_i), g_i(y_i)$ and $d_i(z_i)$ respectively. The government, not individuals and firms, can determine x_i, y_i and z_i through its domestic taxes and other policies.

Each unit of GHG emission causes a damage v to everyone in the world. The precise value of v can be determined by science and economic analysis. For simplicity our assumption implies constant marginal damage of GHG emission. In fact, we could allow any convex damage function and still obtain the same results.

We denote global net GHG emission by $X - Z \equiv \sum_{i=1}^{k}(x_i - z_i)$. It causes a damage $(X - Z)v$ to everyone. People in poor countries suffer more from global warming and are less responsible. If we consider this factor, they should deserve more compensation per capita, which is likely opposed by rich countries and China. For simplicity and political feasibility, we assume an equal damage for everyone.

We let $N \equiv \sum_{i=1}^{k} n_i$ be the world population. The total emission damage to the world is $(X - Z)vN$. This damage may include future and indirect costs, which need not be specifically modelled here.

We let m_i be the money transfer or payment for Country i. Every country determines its emission level to maximize its national welfare, which is its direct utility from energy consumption minus costs and the climate damage to its population, plus the money transfer, as a quasi-linear function:

$$w_i = n_i u_i(x_i + y_i) - v n_i (X - Z) - c_i(x_i) - g_i(y_i) - d_i(z_i) + m_i \tag{1}$$

Eq. (1) differs from consumers' or firms' objective functions, which would not include a country's damage from emission or money transfer. This difference implies that a Pigou tax will not be efficient as will be explained later. Term m_i in (1) implies the marginal utility of income is equal to one. So, one dollar money transfer from a rich country to a poor one does not increase world welfare. The real benefit of money transfer is thus understated. A more realistic assumption of decreasing marginal utility of income will further strengthen our argument for money transfer from developed countries to developing ones.

The total money transfer in the world must be zero. Summing up all countries' welfare functions in (1), we get the world welfare $W \equiv \sum_{i=1}^{k} w_i$ as:

$$W = \sum_{i=1}^{k} \left[n_i u_i(x_i + y_i) - c_i(x_i) - g_i(y_i) - d_i(z_i) \right] - (X - Z)vN \tag{2}$$

This utilitarian welfare function gives everyone an equal weight. It is arguable to give more weights to those in poor countries. This would again strengthen our argument for money transfers but likely reduce political feasibility. So, we choose a conservative utilitarian objective.

Every country's net GHG emission $x_i - z_i$ and population n_i are publicly observable, but utility and cost functions are only known by each country itself. Our goal is to maximize W in (2) when every country maximizes its own w_i in (1).

3. Pigouvian tax does not work

Before showing how our T&C works, we first explain why a global carbon tax or Pigou tax either without money transfer across countries or with fixed transfers is not up to the task. In our model, governments, not consumers or firms, chose x_i, y_i and z_i to maximize national welfare (1) through domestic taxes, subsidies or other policies. A global carbon tax has the following three problems.

(i) Not effective: We first consider a global tax without money transfer, i.e., $m_i = 0$. Then the tax is not imposed on any country as the revenue is retained within. From the government's point of view, no tax appears in (1). Since a carbon tax harms the

[2] Given a fixed n_i, we can also assume that a representative citizen's utility depends on his country's per capita energy consumption, our results hold under both function forms.

economy, a country can secretly refund tax revenue or subsidize energy consumption to cancel the negative impact and still chooses the same x_i, y_i and z_i to maximize (1) given $m_i = 0$. Such a tax, even if officially imposed, will not be effective.[3]

(ii) Not fair: Without money transfer, developing countries will pay higher real costs given the same tax rate. For instance, US per capita income is 30 times of Indian and per capita emission is about 8 – 10 times. A $25 carbon tax per ton is a much lower burden for Americans and the marginal utility loss from carbon reduction is much higher in India. This is against the principle of "equal marginal costs" in terms of real sacrifice. It is unfair also because an average American will effectively receive more tax returns than an Indian, although each unit of emission is penalized equally.

(iii) Not efficient: Now we consider a global tax with money transfer, so that each country is actually penalized for its marginal emission. With a global tax t, m_i becomes $t(x_i - z_i)$ plus some fixed transfer. According to the standard theory, a Pigou tax should be equal to the difference between the social and private marginal costs. Then, the optimal t should be equal to the difference between the world and national damages from a country's one unit emission in (1) and (2), which is $v(N - n_i)$. Given different population across countries, no single tax rate t can do the job and motivate all countries to choose the optimal emissions. A single tax rate only works when it is imposed on infinitesimal agents whose emissions generate the same level of externality, but not on countries, which are significant players and generate different levels of externality on the rest part of the world and must be subject to different effective taxes.

In Tickell's Kyoto 2 (2008) and Meyer's Contraction and Convergence (2000), there will be a single price of emission permits and money returned to each country does not depend on its emission. Both systems will be identical to a global tax with fixed revenue distributions and cannot be efficient. For Rajan's suggestion (2019), if the average per capita emission of 5 tonnes or any given figure is used, it will be similar to the other systems and thus inefficient. Moreover, as the new average emission will be lower than the given one, the total net payment will be negative, and the budget will not be balanced. If the new (yet unknown) average emission is used, his suggestion will be same as our T&C, but his $10 levy per tonne is not proven to be optimal.

Hence, a global tax without money transfer is ineffective and unfair. Even with money transfers a single carbon price in various versions are inefficient. In the next section we show that our T&C is effective, fair and efficient.

4. Equal tax and equal compensation

Given our previous arguments, it is clear that for a global tax to be effective, money transfers across countries are essential; to be fair, the transfer should be based on equal right of emission; to be efficient, countries must face different effective tax rates, not a single tax with lump-sum payments.

Following the two principles of fairness, i.e., equal penalty for each unit of emission and equal compensation for everyone, we propose a global tax on all GHG emissions and distribute the revenue equally to the world population. Given a unit tax t, the total tax revenue is $t(X - Z)$. Everyone receives an equal compensation $t(X - Z)/N$, and Country i receives $t(X - Z)n_i/N$. Therefore, the effective tax rate Country i faces is $t(1 - n_i/N)$. Different from a Pigouvian tax, countries with different population face different effective tax rates and no country receives a lump-sum payment.

We choose the optimal tax rate $t = vN$, equal to the world damage from one unit emission. Country 's payment is $vN(x_i - Z_i)$, and net money transfer $m_i = (X - Z)vn_i - vN(x_i - z_i)$. Substituting this in (1), Country 's welfare under T&C is:

$$w_i = n_i u_i(x_i + y_i) - c_i(x_i) - g_i(y_i) - d_i(z_i) - (x_i - z_i)vN \tag{3}$$

It is clear that the difference between (2) and (3) does not depend on Country i's decisions. Their derivatives with respect to x_i, y_i and z_i are all identical. So, when Country i chooses these variables to maximize its national welfare (3), the first-order conditions are identical to those maximizing (2). When every country maximizes its own welfare, the world welfare will be maximized.

Proposition 1. *With $t = vN$, T&C maximizes the world welfare.*

If we do not know or agree on the value of v, the optimal t can be determined by the required emission reduction to prevent the world temperature from rising 2°C. Given $t = vN$, the first-order conditions for maximizing (3) can be shown as:

$$n_i u_i'(x_i + y_i) - c_i'(x_i) = vN, n_i u_i'(x_i + y_i) = g_i'(y_i), d_i'(z_i) = vN \tag{4}$$

They imply that in every country the marginal net utility of GHG emission and the marginal abatement cost are equal to the marginal world damage of emission, and the marginal cost of green energy equal to the marginal utility. The optimal condition of "equal marginal costs" is hence guaranteed.

The money transfer across countries is justifiable. Every country is penalized according to the damage it causes to the world, $(x_i - z_i)vN$ and receives a compensation equal to its damage caused by the world, $(X - Z)vn_i$. The net transfer is the difference between its damage caused by other countries and other countries' damage caused by its emission. This is fair and consistent with the rule of strict liability, which generally applies to domestic polluters in most countries.

Although mentioned earlier it is worthwhile to emphasize again that, the tax revenue is not returned as lump-sums and each

[3] While Marron and Toder (2014) believe that the Pigou tax can maximize social welfare, they recognize that policymakers often take a US-only view and will make the optimality unattainable.

country receives a part of its payment dependent on its population and does not face the same effective tax rate. Thus, our T&C is not a standard Pigouvian tax.

The next question is: who will benefit from T&C? As countries will change their emissions, the existing emissions do not tell which countries will pay or gain from T&C. To obtain sufficient support for T&C, we need to ensure its benefit to a majority countries based on current emissions. Indeed, we find that T&C always benefits countries with current per capita emission below the world average.

Let subscripts "0" denote current variables without T&C. Country i's status quo welfare in (1) is: $n_i u_i(x_i^0 + y_i^0) - vn_i(X^0 - Z^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0)$. With T&C, if Country i keeps its decisions unchanged, its welfare in (3) would be: $n_i u_i(x_i^0 + y_i^0) - vN(x_i^0 - z_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0)$, which is higher than the original welfare in (1) if $vN(x_i^0 - z_i^0) < vn_i(X^0 - Z^0)$, i.e., $(x_i^0 - z_i^0)/n_i < (X^0 - Z^0)/N$. Under T&C it will change its decisions to maximize its welfare in (3), which must be further higher than (1).

Proposition 2. T&C with $t = vN$ benefits Country i if $\frac{X_i^0 - z_i^0}{n_i} < \frac{X^0 - Z^0}{N}$.

Most developing countries' current per capita emissions are lower than the world average and will benefit. Thus, T&C will have a majority-support in the UN. Countries with per capita emissions slightly above the world average should benefit from T&C too because our condition in Proposition 2 is sufficient, but not necessary. However, it may hurt countries whose per capita emissions are far higher than the world average, and T&C may not be a Pareto improvement over the status quo. Thus, T&C seems to fail the fairness requirement suggested by economists. Nonetheless, in the next section, we show that T&C is a true Pareto improvement over a fair benchmark.

5. Pareto improvement

While a Pareto improvement is often considered as a necessary condition for an agreement on climate change, no such solution has ever been found in the literature. We first show that a Pareto improvement can be achieved by subsidizing GHG reduction with a poll tax (S&T), but it is obviously unfair to developing countries.

Since one unit emission hurts the world by vN, one unit emission reduction must benefit the world by the same amount. Then, we let S&T subsidize each unit reduction by vN. With new net emission $x_i - z_i$, Country i's reduction is $x_i^0 - z_i^0 - x_i + z_i$ and will receive a subsidy of $(x_i^0 - z_i^0 - x_i + z_i)vN$. The total fund required for subsidizing global reduction is $(X^0 - Z^0 - X + Z)vN$.

Under S&T this fund is provided via a poll tax equally shared by the world population. Hence everyone pays $(X^0 - Z^0 - X + Z)$ v, which is the benefit one receives from the reduction. Country 's tax payment is $(X^0 - Z^0 - X + Z)vn_i$. The total tax payment is $(X^0 - Z^0 - X + Z)vN$, equal to the total subsidy. Country 's money transfer m_i now becomes $(x_i^0 - z_i^0 - x_i + z_i)vN - (X^0 - Z^0 - X + Z)vn_i$. Plugging this into its welfare function (1), cancelling the term $(X - Z)vn_i$, we get:

$$w_i = u_i(x_i + y_i) - c_i(x_i) - g_i(y_i) - d_i(z_i) + (x_i^0 - z_i^0 - x_i + z_i)vN - (X^0 - Z^0)vn_i \tag{5}$$

It is clear that (5) is almost identical to (3) except for fixed terms $(x_i^0 - z_i^0)vN$ and $-(X^0 - Z^0)vn_i$, which should have no impact on Country i 's decisions. When Country i chooses x_i, y_i and z_i to maximize its national welfare (5), it must maximize the world welfare. Hence, S&T is Pareto efficient, i.e., motivating every country to maximize the world welfare, same as T&C.

Proposition 3. *S&T motivates every country to maximize the world welfare.*

Not only Pareto efficient, S&T is also a Pareto improvement over the status quo. If Country i keeps its original decisions under S&T as if there is no agreement, its welfare in (5) becomes $u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - vn_i(X^0 - Z^0)$, which is its status quo welfare (1) with $m_i = 0$. Since it can improve its welfare by choosing the optimal decisions, not x_i^0, y_i^0 and z_i^0, it must be better off under S&T.

Proposition 4. *Under S&T every country is better off than the status quo.*

Given Propositions 3 and 4, we see that S&T is Pareto improving as well as efficient, thus satisfying both economists' requirements. Nevertheless, our intuition tells us that S&T is unfair for obvious reasons. (i) Subsidizing reduction implies that the more a country emits currently, the more subsidy it receives. A country receives a positive lump-sum if and only if $(x_i^0 - z_i^0)vN > (X^0 - Z^0)vn_i$, i.e. its current per capita emission $(x_i^0 - z_i^0)/n_i$ is higher than the world average $(X^0 - Z^0)/N$. This is unfair to countries with low per capita emissions. (ii) A country's subsidy $(x_i^0 - z_i^0 - x_i + z_i)vN$ exceeds its tax payment $(X^0 - Z^0 - X + Z)vn_i$ if and only if its per capita emission reduction $(x_i^0 - z_i^0 - x_i + z_i)/n_i$ exceeds the world average, $(X^0 - Z^0 - X + Z)/N$. Poor countries cannot do so and have to pay rich countries for their emission reductions. (iii) Taxing everyone equally, i.e., a poll tax, is universally considered regressive and unfair.

Despite these unfair treatments poor countries are still better off under S&T only because their status quo positions are so bad. It reveals that a Pareto improvement is not a good standard for fairness. It is justifiable only if the status quo is a fair benchmark, which is obviously not due to huge asymmetry of negative externality generated by GHG emissions. This raises a question of whether a Pareto improvement should be an essential requirement in a climate change agreement. Moreover, this requirement implies a double standard, as no one requires a Pareto improvement when a domestic polluter is fined within any country.

The status quo could only be a fair benchmark after the emitters are penalized and victims duly compensated. This can be achieved hypothetically by a tax rate $t = vN$ on each country's current emission $x_i^0 - z_i^0$ and compensating everyone equally by his/her damage $v(X^0 - Z^0)$. If so, Country i should receive a net payment $n_i v(X^0 - Z^0) - vN(x_i^0 - z_i^0)$. Then this compensated status quo would be a fair benchmark. Adding its net payment to (1) as m_i, we get Country i 's welfare under current emissions:

$$w_i^0 = n_i u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - vN(x_i^0 - z_i^0) \quad (6)$$

If Country i chooses its current emissions under T&C, its welfare in (3) will yield the same result as (6). When it chooses its optimal emissions in (3), its welfare must be higher than (6). So, T&C must make every country better off than the compensated benchmark, i.e., a true Pareto improvement.

Proposition 5. *T&C is a Pareto improvement over the compensated benchmark.*

If we recognize the compensated benchmark as a fair basis for comparison, T&C provides an efficient and fair solution, maximizing the world welfare and benefiting every country. Both requirements for an ideal agreement are satisfied.

A question remains, however, countries may not agree on the value of v, especially some big emitters may not agree on the efficient tax level vN, even if they could not openly challenge the two fairness principles. They may argue for a lower value of v, thus under-evaluate the damage of GHG emission. In the next section we will show that in this case T&C is still better than no agreement.

6. T&C with $t < vN$

If some countries do not accept the tax level vN, a universal agreement may be only reachable with a lower tax rate $t < vN$. Given $0 < t < vN$, every unit of GHG emission is still penalized equally and everyone receives an equal compensation. As $m_i = t(X - Z)n_i / N - t(X_i - Z_i)$, Country i 's welfare becomes:

$$w_i = u_i(x_i + y_i) - c_i(x_i) - g_i(y_i) - d_i(z_i) - n_i v(X - Z) - t(x_i - z_i) + (X - Z)\frac{tn_i}{N} \quad (7)$$

Given concave utility and convex cost functions, it is easy to see that function w_i is strictly concave in x_i, y_i and z_i. We find that when each country chooses x_i, y_i and z_i to maximize w_i in (7), it will lead to a unique equilibrium (Appendix A).

Proposition 6. *T&C with any $t < vN$ leads to a unique equilibrium.*

The next question is how a country's choices of x_i, y_i and z_i are affected by the tax rate t. With $t < vN$, T&C does not motivate every country to maximize the world welfare. Nonetheless, our intuition suggests that a carbon tax should reduce every country's emission x_i, increase its green energy y_i and abatement z_i. Thus, we expect world welfare rises with t. Indeed, we can show this is true (see Appendix B).

Proposition 7. *Under T&C with $t < vN$, a higher t always reduces every x_i, raises every y_i, z_i and the world welfare.*

This result provides a focal point for the public support on climate protection. Instead of demanding unspecified "more actions", the climate activists can simply call for a higher tax rate to be agreed by COPs. Furthermore, we can show that given any sub-optimal tax rate, T&C still benefits countries with current per capita emissions below the world average.

Proposition 8. *T&C with $t < vN$ benefits Country i if $\frac{x_i^0 - z_i^0}{n_i} < \frac{X^0 - Z^0}{N}$.*

Proof: Given $t < vN$, Country i 's welfare (7) will be lower when $X - Z$ is replaced by higher value of $X^0 - Z^0$. In addition, if it keeps its original decisions, its welfare will be $u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - \left(n_i v - \frac{tn_i}{N}\right)(X^0 - Z^0) - t(x_i^0 - z_i^0)$, which is larger than its status quo, $u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - n_i v(X^0 - Z^0)$, if $\frac{tn_i}{N}(X^0 - Z^0) > t(x_i^0 - z_i^0)$, i.e., $\frac{x_i^0 - z_i^0}{n_i} < \frac{X^0 - Z^0}{N}$. Its welfare in (7) must be further higher when it adjusts its decisions under T&C rather than keeping the original ones. ||

Therefore, we have a good reason to implement an imperfect T&C with $t < vN$, to help poor countries as well as climate protection. What about countries with higher per capita emissions than the world average? Under perfect T&C with $t = vN$, we have shown that, all countries will be better off over the compensated benchmark. With $t < vN$, this is not guaranteed. However, we can show that, it holds for countries whose current per capita emissions are higher than the new world average.

Proposition 9. *T&C with $t < vN$ benefits Country i over the compensated benchmark if $\frac{x_i^0 - z_i^0}{n_i} > \frac{X - Z}{N}$.*

Proof: From (6), a country's compensated benchmark is $u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - vN(x_i^0 - z_i^0)$. Under T&C if it keeps original decisions, its welfare in (7) is $n_i u_i(x_i^0 + y_i^0) - c_i(x_i^0) - g_i(y_i^0) - d_i(z_i^0) - n_i v(X - Z) - t(x_i^0 - z_i^0) + n_i t(X - Z)/N$.

The latter is higher if $vN(x_i^0 - z_i^0) - n_i v(X - Z) - t(x_i^0 - z_i^0) + n_i t(X - Z)/N > 0$, which holds if $(vN - t)\left(x_i^0 - z_i^0 - \frac{X - Z}{N}n_i\right) > 0$, i.e., $\frac{x_i^0 - z_i^0}{n_i} > \frac{X - Z}{N}$.

Since $X^0 - Z^0 > X - Z$, Proposition 9 implies a country must be better off if its current per capita emission is higher than the current world average. Propositions 8 and 9 together imply that every country is better off either over the status quo or the compensated benchmark, countries with $\frac{X - Z}{N} < \frac{x_i^0 - z_i^0}{n_i} < \frac{X^0 - Z^0}{N}$ are better off over both, and no country is worse off over both. This again provides a moral argument to press high emitters to accept T&C. If they duly pay the externality they impose on others, they will lose more than from T&C.

However, as we know, T&C with a very low tax rate will not reduce GHG emissions significantly. We propose a potential solution to solve this problem next.

7. Pyramid T&C system

If some high emitters only accept a very low $t < vN$, we propose a pyramid T&C system based on the principle of equal compensation among equal-tax payers. It allows countries to choose different levels of contribution. Different from Gaspar and Parry (2021), our multi-tax system generally does not require developed countries to face higher tax rates than developing ones. Instead, it allows the opposite to happen as long as equal compensation is in place to ensure the fairness of the whole system.

We assume that every country agrees that any tax revenue should be distributed equally among the taxpayers but may not agree with the tax level. Our system works as follows. First, all countries accept a basic tax rate t under the condition of equal compensation, and the T&C will be implemented globally as described previously.

Then a higher tax rate t_1 will be agreed by a voluntary group. The extra tax rate $t_1 - t$ is charged on their emissions and the revenue is distributed equally in the group. Each country has an extra net payment of $(t_1 - t)[x_i - z_i - (X_1 - Z_1)n_i/N_1]$, where $X_1 - Z_1$ is the total net emission from the group and N_1 is the group population. Furthermore, an even higher t_2 can be agreed by a smaller group within the first and the extra revenue is equally distributed accordingly and so on. The sum of net payment is zero within each group, so the budget is always balanced. It is a pyramid of clubs with different levels of commitments to climate protection.

Under this system, every country faces a carbon tax it commits to. The higher this tax is, the closer its emission will be to the optimal level to maximize world welfare. So long as a country chooses a positive tax, it will reduce its emission and will pay if its per capita emission is higher than the group average. A country with a high per capita emission is likely to choose a low tax, but still contributes by paying other countries for that level of damages. Conversely, a country with a low per capita emission is likely to choose a high tax and receives a positive net transfer from the voluntary group members. According to Proposition 8, members with lower than the average per capita emission will always benefit from T&C within each group. Thus, developing countries are willing to join in high-tax clubs.

Another advantage of this pyramid system is its dynamic feature. After a country commits to an initial tax level, its emission tends to fall. Consequently, its tax payment will go down, which encourages it to commit to a higher tax rate and join in a higher club. Countries paying low taxes will face an increasing political pressure and may become a shrinking minority. It would be difficult for any country to refuse to pay reasonable taxes expected by the world community. There can be a race to the top rather than to the bottom. Eventually we may approach the ideal T&C with $t = vN$.

8. Conclusion

We have shown that our two principles of fairness automatically lead to a specific solution of T&C which is fair and efficient. Nevertheless, some countries may oppose it based on national sovereignty. This argument is problematic because GHG emissions cause fatal damages to other countries and violate their sovereignty. If one country should pay for dumping pollutants into its neighbour's territory, it should also pay when its GHG emission hurts the world. Most of the world population will gain from T&C and can put a pressure on a few high per capita emitters. This is easier than to pressurise countries with different conditions to reach carbon neutrality at arbitrary dates or other GHG emission targets, such as phasing out coal or transition away from fossil fuel. Each country may still argue for its special case of lower payments with various historical or circumstantial reasons. Nonetheless, under this simple and transparent framework political pressure can be more focused than in previous COPs. If the public accepts T&C based on well understood simple principles of fairness, politicians will have less room to manipulate the political resistance or reverse existing agreements. Thus, an effective, fair, and efficient international agreement may be reached and maintained to motivate the whole world to save climate.

Declaration of competing interest

None.

Appendix A. Proof for Proposition 6

Given our concavity assumption it is easy to prove the existence of an equilibrium. To show its uniqueness, we differentiate (7) with respect to x_i, y_i and z_i, and obtain FOC:

$$u_i'(x_i + y_i) - c_i'(x_i) = t\left(1 - \frac{n_i}{N}\right) + vn_i \tag{A1}$$

$$u_i'(x_i + y_i) = g_i'(y_i) \tag{A2}$$

$$d_i'(z_i) = t\left(1 - \frac{n_i}{N}\right) + vn_i \tag{A3}$$

Suppose there are two equilibria with (x_i, y_i, z_i) and (x_i', y_i', z_i').

First, (A3) implies $d_i'(z_i) = d_i'(z_i')$, i.e., $z_i = z_i'$ for any i. Similarly, (A1) implies:

$$u_i'(x_i+y_i) - c_i'(x_i) = u_i'(x_i'+y_i') - c_i'(x_i') \tag{A4}$$

If $x_i > x_i'$, we have $c_i{}'(x_i) > c_i{}'(x_i')$, which implies $u_i{}'(x_i + y_i) > u_i{}'(x_i' + y_i')$, i.e. $x_i + y_i < x_i' + y_i'$. Given $x_i > x_i'$, this implies $y_i < y_i'$. So we have $g_i{}'(y_i) < g_i{}'(y_i')$. Then (A2) implies $u_i{}'(x_i + y_i) < u_i'(x_i' + y_i')$, contradicting to the earlier conclusion. Hence $x_i \leq x_i'$ for any i. By symmetry, we must have $x_i' \leq x_i$. So, $x_i = x_i'$ for any i. Furthermore, this and (A1) implies $y_i = y_i'$ for any i. The equilibrium must be unique.

Appendix B. Proof for Proposition 7

(A3) implies $d_i{}'(z_i)$ must rise when t does. As $d_i(z_i)$ is convex, z_i must rise with t.

Assume x_i rises with t. Then, $c_i'(x_i)$ must rise, (A1) implies that $u_i{}'(x_i+y_i)$ must rise too, which implies $x_i + y_i$ falls since $u_i(x_i+y_i)$ is concave. If x_i rises and $x_i + y_i$ falls, y_i must fall. So, $g_i'(y_i)$ falls, since $g_i(y_i)$ is convex. Then, (A2) implies $u_i{}'(x_i+y_i)$ must fall. This is a contradiction to our earlier conclusion. Hence, x_i must fall with t.

Then assume y_i falls with t. As x_i falls, $x_i + y_i$ must fall, which implies $u_i{}'(x_i+y_i)$ rises. Thus, (A2) implies $g_i'(y_i)$ rises, which is impossible, so, y_i must rise with t.

Differentiate W in (2) with respect to x_i, y_i and z_i, we get

$$\frac{\partial W}{\partial x_i} = u_i^{\cdot}(x_i+y_i) - c_i^{\cdot}(x_i) - vN, \frac{\partial W}{\partial y_i} = u_i^{\cdot}(x_i+y_i) - g_i^{\cdot}(y_i), \frac{\partial W}{\partial z_i} = vN - d_i^{\cdot}(z_i)$$

(A2) implies $\frac{\partial W}{\partial y_i} = 0$. As $t < vN$, (A1) implies $\frac{\partial W}{\partial x_i} < 0$, and (A3) implies $\frac{\partial W}{\partial z_i} > 0$.

Hence, W is not affected by y_i, but must increase as t reduces x_i and raises z_i.

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