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Optimal Carbon Taxes and Foreign Aid

Geir H. M. Bjertnæs

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Abstract

This article explores whether altruistic preferences toward households in poor high-temperature countries stimulate global warming policies within rich low-temperature countries that avoids damage from global warming. The article analyzes optimal carbon taxes on commodities within such rich low-temperature countries when damage inflicted upon poor high-temperature countries are accompanied with foreign aid. The article contributes to the literature by identifying two cases where the second-best optimal carbon tax for such rich countries exceeds the marginal damage inflicted on poor countries. First, when rich countries place a higher altruistic welfare weight on environmental damage than on economic well-being within poor countries. Second, when foreign aid is hampered by taxes within aid-receiving countries. The article also identifies cases where the Pigouvian tax implements the social planner solution. Hence, altruistic preferences and foreign aid contributes to solve the free-rider problem associated with global warming.

Keywords: Optimal taxation, Foreign aid, Carbon tax, Global warming, Free-riding.

JEL classification: H2 H21 H23 Q58 R48

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Address: P.O. BOX 2633, St. Hanshaugen, Oslo 0131, Norway, Statistics Norway, Research Department. E-mail: ghb@ssb.no

Sammendrag

Klimaendringer er en av de største utfordringene i det 21. århundre. Utslippene av klimagasser må reduseres for å begrense økningen i den globale gjennomsnittstemperaturen, som hovedsakelig rammer fattige land rundt ekvator. Gratispassasjerproblemet er imidlertid et hinder for en global klimaavtale som implementerer en slik politikk. Det er derfor ønskelig å avdekke rike lands insentiver til å skattlegge utslipp i fravær av globale avtaler.

Denne studien bidrar ved å beregne optimaliserte karbonskatter på varer i rike land med altruistiske preferanser når skade som påføres fattige land kombineres med u-hjelp. Skatter som implementerer den sosiale planleggerløsningen sammenlignes med Pigou-løsningen, der miljøskatten tilsvarer den marginale miljøskaden, samt med nest-beste optimale skatter som er utformet for å øke skatteinntektene. Altruistiske preferanser implementeres ved å inkorporere miljøskade og konsum i fattige land i velferdsfunksjonen til rike land.

Studien bidrar til litteraturen om karbonskatt og u-hjelp ved å vise at den sosiale planlegger-løsningen med nøytral altruisme, dvs. med like velferdsvekter på miljøskade og konsum i fattige mottakerland, implementeres når skattesatsene på ikke-forurensende goder er identiske, og ekstra skatten på det forurensende godet tilsvarer den marginale skaden påført husholdningene i det fattige landet. Ekstraskatten på forurensende goder overstiger den marginale skaden i tilfellet med paternalistisk altruisme, dvs. der velferdsvekten knyttet til miljøskade overstiger velferdsvekten knyttet til konsum i fattige land.

Studien bidrar også til litteraturen om optimal beskatning av konsumgoder ved å vise at den nest-beste optimale skatteforskjellen mellom forurensende og ikke-forurensende goder i rike land som donerer u-hjelp tilsvarer den marginale skaden påført fattige land når altruismen er nøytral, og goder ikke er skattlagt i det fattige mottakerlandet. Studien viser også at den nest-beste optimale skatteforskjellen mellom forurensende og ikke-forurensende goder er høyere enn den marginale skaden som påføres fattige land når altruismen er paternalistisk i favør av miljøet, samt når varer er skattlagt i mottakerlandet.

Studien viser altså at gratispassasjerproblemet forbundet med innføring av klimapolitikk reduseres når rike land har altruistiske preferanser for husholdninger i fattige land som mottar u-hjelp. Disse resultatene er basert på en stilisert teoretisk modell og bør derfor ikke brukes uten grundige refleksjoner.

1. Introduction

Climate change is one of the most pressing challenges of the 21st century. The world needs to reduce greenhouse gas (GHG) emissions to limit the damage mainly inflicted upon poor high-temperature countries around the equator, see IPCC's Sixth Assessment Report and Tol (2021). A major obstacle is the lack of a global cooperative solutions where all countries implement emission reduction policies. The global outcome therefore depends on unilateral efforts by countries and regions. Such efforts have been mixed as some countries seem to free-ride while other countries and regions have implemented ambitious climate policy measures. Indeed, one may question whether it is in the interest of a rich carbon-based country to implement ambitious climate policy measures. A key research topic is therefore to uncover rich low-temperature countries incentives to tax GHG emissions within non-cooperative solutions when emissions mainly hurt poor high-temperature countries.

The present study contributes by calculating optimal carbon taxes on commodities within rich low-temperature countries with altruistic preferences towards households in poor countries when damage inflicted upon poor high-temperature countries are combined with foreign aid. Second-best optimal taxes designed to raise tax revenue and taxes which implement the social planner solution are compared with the Pigouvian solution, where the environmental tax equals the marginal damage. Altruistic preferences are implemented by incorporating environmental damage and economic well-being within poor countries into the welfare function of rich countries. The study assumes altruistic preferences as foreign aid is donated to poor countries without strategic motives, and as costs of climate measures by fare exceeds own benefits within some rich countries. Also, foreign aid schemes were judged to be more cost effective at lowering poverty compared to emission reduction policies according to the Copenhagen Consensus expert group. The study illuminates on these features by including scenarios with pure altruism and with paternalistic altruism.

The study contributes to the literature on carbon taxation and foreign aid by showing that the social planner solution with pure altruism, i.e. with equal welfare weights on damage and economic well-being in poor aid-receiving countries, is implemented when tax rates on non-polluting goods are identical, and the additional tax on the polluting good equals the marginal damage inflicted on households in the poor country. The intuition is that the damage of pollution measured in units of clean goods based on the welfare function equals the damage of pollution measured in units of clean goods evaluated by households within the poor country. Hence, a tax on pollution equal to this damage implements the social planner solution. The additional tax on polluting goods exceeds the marginal damage in the case with paternalistic altruism in favor of the climate, i.e. where the welfare weight attached to damage exceeds the welfare weight attached to economic well-being. The intuition is that the additional tax on polluting goods within the social planner solution equals the marginal damage of pollution measured as compensation in units of clean goods based on the welfare function. The compensation in units of clean goods based on the welfare function exceeds the compensation required by individuals in the poor country. The compensation required by individuals in the poor country equals the Pigouvian tax. Hence, the additional tax on polluting goods within the social planner solution exceeds the Pigouvian tax in this case. These findings are mere applications of theoretical insights from the literature. The contribution to the literature consists of arriving these tax-results in scenarios with altruism and foreign aid.

The study also contributes to the second-best literature by showing that the second-best optimal tax difference between polluting and clean goods within rich aid-donating countries equals the marginal damage inflicted upon poor countries when altruism is pure, and goods are not taxed within the poor aid-receiving country. The tax difference equals the marginal damage within the poor country because welfare weights on emission reductions and foreign aid is identical, and because foreign aid links the value of public funds in the aid-donating country to the value of private income in the poor aid-receiving country. Hence, the environmental tax is not adjusted for the marginal cost of public funds in this case. The study further shows that the second-best optimal tax difference between polluting and clean goods within rich aid-donating countries exceeds the marginal damage inflicted upon poor countries when paternalistic altruism favors the climate and/or when goods are taxed within the poor aid-receiving country. Hence, the second-best optimal tax exceeds the Pigouvian tax in this case. Several studies claim that the revenue raising second-best optimal additional tax on polluting goods is below the Pigouvian tax, i.e. below the marginal environmental damage, see e.g. Sandmo (1975) and Bovenberg and de Mooij (1994). The present study arrives at the opposite conclusion in cases with altruistic preferences and foreign aid. Hence, the study shows that altruistic preferences for households in poor countries which receives foreign aid contributes to solve the free-rider problem associated with damage of global warming inflicted on poor aid-receiving countries. One may argue that poor countries underestimate the cost of global warming as compensation requirements for damage are modest when households are poor. Such issues are beyond the scope of the present study, however.

2. The literature

Pigou (1920) argued that the optimal pollution tax equals the marginal external damage caused by the polluting activity. However, this Pigouvian principle has been challenged by the theory of second best, which takes into account the presence of other distortions in the economy, such as preexisting taxes on labor and consumption. Key insights from the theory of second best are exploited to arrive at optimal environmental taxes in the presence of altruistic preferences and foreign aid. Relevant contributions from the theory of second best are presented in the following sections.

One of the first papers to question the Pigouvian principle was Sandmo (1975). He showed that the marginal environmental damage should be divided by the marginal cost of public funds, which is typically greater than one, to obtain the optimal corrective tax. This result implies that the government should trade off the environmental benefit of reducing pollution with the efficiency cost of raising revenue through distortionary taxation. Sandmo (1975) also derived an additivity property, which states that the marginal value of the externality enters additively into the commodity tax formula for the externality generating good, while commodity tax formulas of clean goods take the same form as in the absence of any externality.

The literature on environmental taxation has discussed the possibility of achieving a double dividend, i.e., improving both environmental quality and economic efficiency, by using the revenue from the pollution tax to reduce distortionary taxes. Bovenberg and de Mooij (1994) argued that the tax interaction effect is stronger than the revenue-recycling effect, and hence, rejects the double dividend hypothesis. Bovenberg and de Mooij (1994) choose a normalization where the tax on the clean good equals zero. With this normalization, the optimal pollution tax is lower than the marginal external damage, as in Sandmo (1975). However, they also acknowledged that other normalizations are possible and sometimes preferable, depending on the policy context. Fullerton (1997) and Schob (1997) explore the role of normalization in more detail and show that it is the difference between the tax on the polluting good and the tax on the clean good that is less than the Pigovian rate. Fullerton (1997) further shows that if the tax on the polluting good equals zero, the same second-best optimum can be achieved using a higher tax on labor and a subsidy to clean consumption. He concludes that a tax system with environmental subsidies may be no different from one with an environmental tax since they can achieve the exact same equilibrium solution.

The double dividend literature asks whether the second-best optimal environmental tax is higher or lower than the first-best Pigouvian rate. This question is not answered directly according to Jaeger

(2011), because the first-best Pigouvian rate is replaced by a definition of marginal social damages, the value of which changes with the tax level and tax normalization. He further shows that tax formulas presented in Sandmo (1975) is unable to determine whether the second-best optimal tax difference between polluting and clean goods is higher or lower than the Pigouvian rate. Jeager (2011) finally shows that the need for tax revenue contributes to increase the optimal environmental tax difference above the Pigouvian tax rate. Bjertnæs et al. (2013) shows that the second-best optimal carbon tax exceeds the quota price when the marginal cost of public funds exceeds one and the government is responsible for purchasing quotas, which is the case within the effort sharing regulation in EU. The carbon tax is not adjusted for the marginal cost of public funds as the damage, quota purchases, is shifted to the government budget. The present study contributes to the second-best literature by showing that the second-best optimal tax difference between polluting and clean goods within rich aid-donating countries equals the marginal damage inflicted upon poor countries when altruism is pure, and goods are not taxed within the poor aid-receiving country. The study further shows that the second-best optimal tax difference between polluting and clean goods exceeds the marginal damage inflicted upon poor countries when paternalistic altruism favors the climate and/or when goods are taxed within the poor aid-receiving country.

The literature on environmental taxation has also considered more general settings with heterogenous agents and redistribution. Kaplow (2012) shows that setting commodity taxes and subsidies equal to marginal harms and benefits is optimal within a model framework with utility weakly separable in labor and no preference heterogeneity. Jacobs and de Mooij (2015) show that the second-best optimal tax on an externality-generating good equals the Pigouvian tax within a model framework with heterogeneous agents, general preference structures and allowing for both linear and non-linear optimal tax schedules. The second-best optimal environmental tax should not be corrected for the marginal cost of public funds because the marginal cost of public funds equals unity within optimal tax systems according to Jacobs and de Mooij (2015). Jacobs and van der Ploeg (2019) find that if Engel curves are linear, optimal pollution taxes should follow the first-best rule for the Pigouvian corrective tax even if the government wants to redistribute income and the poor spend a disproportional part of their income on polluting goods. Aronson and Sjøgren (2018) show that Sandmo's (1975) additivity property applies in a static benchmark model with an atmospheric consumption externality, where the government uses a mix of a nonlinear income tax and linear commodity taxes. They show that a term which measures the marginal value of the externality enters additively into the commodity tax formula for the externality generating good, while commodity tax formulas of clean goods and marginal income taxation take the same form as in the absence of any externality. The social value of a cleaner environment also reflects how a change in the level of environmental damage affects the scope for redistribution within their model framework. Hence, the government has an incentive to adjust the tax on the polluting good when environmental quality or the polluting good is a complement or substitute for leisure. Gahvari (2014), on the other hand, argues that the search for a tax component which measures the marginal value of the externality is often impossible because of the interconnectedness between labor supply, consumption decisions and the environmental quality.

Several articles explore how altruistic behavior affect optimal pollution taxes. Johansson (1997) analyzes how different kinds of altruistic behavior would affect optimal externality-correcting taxes. He finds that the Pigouvian tax is optimal under pure altruism in large populations. He also shows that one cannot generally conclude that the optimal tax should be lower than the "standard" Pigouvian tax level just because individuals decrease their consumption of externality-causing goods in altruistic response to others' externality-induced loss of utility. Howarth (1996) argues that altruistic preferences do not substantively affect the incentives faced by individual consumers which consumes externality-causing goods as his/her “altruistic actions would be swamped by the sheer scale of the economy”. Hence, serving altruistic desires “becomes a public good that is best provided by collective institutions”. Howarth (1996) also shows that the efficient pollution tax exceeds the sum of individuals' marginal willingness to pay for pollution abatement when individuals have preferences for status, and that altruistic preferences does not substantively alter this tax. Daube and Ulph (2016) argue that free-riding is not necessarily associated with self-interested behavior. They show that free-riding will arise in the presence of altruistic preferences if individuals’ emissions are negligible relative to the total. Hence, the optimal Pigouvian tax is independent of the degree of altruism. Daube and Ulph (2016) also show that the Pigouvian tax is optimal when individuals cut back on their consumption of polluting goods due to altruism and a Kantian form of behavior. Daube (2019) show that non-cooperative governments internalize some of the damage inflicted on other countries when individuals have altruistic preferences, and that such damage is incorporated into the optimal environmental tax. He also shows that the cooperative global optimum changes as altruism leads individuals to effectively experience damage in other countries as well as the direct damage. Several other studies explore the sustainability of cooperative solutions for public goods provision. The aim of the present study is limited to noncooperative solutions, however.

The literature on carbon taxation and foreign aid is mainly concerned with aid which stimulates climate policies within poor countries. The aim of the present study is to illuminate on optimal carbon taxes within rich aid-donating countries with altruistic preferences for households in poor countries when externalities inflicted on households in poor countries are combined with foreign aid. The aim is not to resolve issues related to taxation of externalities and interconnectedness between labor supply, consumption decisions, environmental quality, or the distribution of income within a country. The model framework, which is closely related to the framework in Sandmo (1975), is tailor made to answer this research question. The Pigouvian tax definition in Bovenberg and de Mooij (1994) and Gahvari (2014) is employed to compare with optimal environmental tax rates that are independent of normalization, see Orosel and Schob (1996). The approach in Howarth (1996) and Daube and Ulph (2016) is adopted by assuming that the government behaves altruistic when determining taxes and foreign aid within a model framework where individuals do not adjust their consumption of externality-causing goods due to altruistic preferences.

The present study contributes to the literature on carbon taxation and foreign aid by showing that the Pigouvian tax is part of the tax system which implements the social planner solution within donating countries when altruism is pure. The study further shows that the tax difference between polluting and clean goods exceeds the Pigouvian tax rate when altruism is paternalistic in favor of the climate. These findings are mere applications of theoretical insights in Johansson (1997), Daube and Ulph (2016) and Daube (2019). However, the study contributes with new insights to the theory of second best by identifying two cases where the second-best optimal tax difference between polluting and clean goods exceeds the marginal damage inflicted upon poor countries. Hence, the study shows that altruistic preferences for households in poor countries which receives foreign aid contributes to solve the free-rider problem associated with damage of global warming inflicted on poor aid-receiving countries.

3. The social planner solution

The model framework is designed to calculate the social planner solution of clean and polluting goods, as well as optimal pollution tax formulas, both Pigouvian and revenue raising. The utility of individual i within the rich aid-donating country, U_r^i, is a function of selfish utility, $u(X^i)$, where $X^i = x_1^i, .., x_n^i$ denotes the vector of consumer goods for individual i, plus altruistic utility based on the utility of each household within the poor aid-receiving country. The utility of a representative household in the poor country, $b(C) - d(X_1)$, is a function of the household's consumption vector, $C = c_2, .., c_n$, and the damage of emissions inflicted on each individual, $d(X_1)$. The damage is a function of accumulated consumption of the polluting good within the rich country, $X_1 = x_1^1 + .. + x_1^N$, where N denotes the number of individuals within the rich country. Hence, it is assumed that the polluting good is not consumed by households within the poor country. The utility of individual i within the rich country is given as

$$U_r^i = u(X^i) + \sum_{j=1}^{M}\big(\rho b(C) - \sigma d(X_1)\big) \text{, for } i = 1, ., N. \quad (1)$$

The number of individuals in the poor country equals M. The welfare weight attached to each poor household's utility from consumer goods and damage is denoted ρ and σ, respectively. The welfare of the rich country, W, is given by the Samuelson- Bergson welfare function

$$W = \sum_{i=1}^{N} u(X^i) + \sum_{i=1}^{N}\sum_{j=1}^{M}\big(\rho b(C) - \sigma d(X_1)\big). \quad (2)$$

The welfare of a representative households within the rich country, u_r, is found by assuming identical consumption bundles across individuals and dividing the welfare function, W, by the number of individuals, N, i.e.

$$u_r = u(X) + M\rho b(C) - M\sigma d(Nx_1), \quad (3)$$

where top scripts of consumption vectors are skipped. Consumption of the polluting good, X_1, equals the number of rich individuals multiplied by each rich household's consumption of the polluting good, Nx_1. Simplifying notation by assuming that $d(Nx_1) \equiv e(x_1)$, $M\rho = \varphi$ and $M\sigma = \psi$ implies that

$$u_r = u(x_1, x_2, \dots, x_n) + \varphi b(c_2, \dots, c_n) - \psi e(x_1). \quad (4)$$

It is assumed that production of goods i in the rich country, x_i, is linear in labor, l_i. It is also assumed that there is no production of goods within the poor country, and that the number of households in the rich country, N, equals the number of households in the poor country, M. These simplifying assumptions implies that

$$x_i + c_i = \alpha l_i, \text{ for } i = 1, \dots, n. \quad (5)$$

Where α denotes labor productivity, and $c_1 = 0$. Foreign aid of each consumer good amounts to c_i. The supply of labor by the representative individual within the rich country, L, is fixed. Hence,

$$l_1 + \dots + l_n = L. \quad (6)$$

The social planner solution is found by maximizing the welfare function

$$\underset{l_1,\dots,l_n,c_2,\dots,c_n}{\text{Max}} \; u(\alpha l_1, \alpha l_2 - c_2, \dots, \alpha l_n - c_n) + \varphi b(c_2, \dots, c_n) - \psi e(\alpha l_1) \quad (7)$$

Given $l_1 + \dots + l_n = L$.

The damage function, $e(\alpha l_1)$, takes into account that an increase in consumption of the polluting good by the representative household in the rich country generates damage equivalent to an increase in consumption of all households in the rich country. The number of poor households is included multiplicatively in the welfare weight on damage, ψ. Hence, the public good nature of altruism associated with emission reductions is incorporated into this welfare weight. The number of poor households is also included multiplicatively in the welfare weight on the utility of consumer goods within the poor country. Hence, the public good nature of altruism and foreign aid is incorporated into these welfare weights. Assuming identical welfare weights, $\varphi = \psi$, imply identical welfare weights attached to the utility of damage and consumer goods within poor households' utility functions. Such preferences are often labeled pure altruism. First order conditions imply that, see appendix A.

$$\frac{u'_{x_1}}{u'_{x_i}} - \frac{\psi e'_{x_1}}{\varphi b'_{c_i}} = 1 \text{ for } i = 2, \dots, n, \quad (8)$$

and

$$\frac{u'_{x_j}}{u'_{x_i}} = \frac{b'_{c_j}}{b'_{c_i}} \text{ for } i = 2, \dots, n \text{ and } j = 2, \dots, n. \quad (9)$$

Equation (8) implies that the marginal rate of substitution between good 1 and good i based on the welfare function within the rich country, including the impact of the negative externality connected with good 1, equals the marginal rate of transformation. Hence, the amount of clean goods required to compensate for one unit less of the polluting good, given that the utility effect of the reduced pollution is taken into consideration, equals the reduction in clean goods required to produce an additional unit of the polluting good. The marginal damage of pollution measured in units of clean goods based on the welfare function, $\frac{\psi e'_{x_1}}{\varphi b'_{c_i}}$, equals the marginal damage of pollution measured in units of clean goods evaluated by households within the poor country, $\frac{e'_{x_1}}{b'_{c_i}}$, in the case with identical welfare weights, i.e. where $\varphi = \psi$.

Equation (8) also implies that the marginal rate of substitution between clean goods and the polluting good within the rich country excluding externalities, $\frac{u'_{x_1}}{u'_{x_i}}$, minus the marginal damage of pollution measured in units of clean goods evaluated by the household in the poor country, $\frac{e'_{x_1}}{b'_{c_i}}$, exceeds the marginal rate of transformation in the case where the welfare weight attached to damage of pollution exceeds the welfare weight attached to economic well-being, i.e. $\frac{u'_{x_1}}{u'_{x_i}} - \frac{e'_{x_1}}{b'_{c_i}} > 1$ for $i = 2, .., n$ when $1 > \psi > \varphi$. Such preferences are often labeled paternalistic altruism. The explanation is that a higher relative welfare weight on environmental damage implies a lower optimal level of foreign aid relative to emission reductions. This contributes to lower the marginal damage measured in units of clean goods evaluated by households in the poor country compared to the damage based on the welfare function for the rich country. Hence, the marginal rate of substitution between clean and polluting goods minus damage measured in units of clean goods by households in the poor country exceeds the marginal rate of transformation in this case.

4. Taxation and the social planner solution

This section identifies tax systems which implements the social planner solution. The section also explores whether the Pigouvian solution is part of these tax systems. The analysis assumes that optimizing households and firms operate in perfect competition markets.

4.1. Households and firms

The representative household in the rich country maximizes utility given their budget constraint

$$\underset{x_1,..,x_n}{\text{Max}}\ u(x_1,\dots,x_n) \tag{10}$$

Given $p_1x_1+\ldots+p_nx_n = y_r$.

p_i denotes the consumer price of good i, and y_r denotes income. First-order conditions imply that

$$\frac{u'_{x_j}}{u'_{x_i}} = \frac{p_j}{p_i} \text{ for } i = 1,\dots,n \text{ and } j = 1,..,n. \tag{11}$$

The representative household within the poor country maximize utility given their budget constraint. First order conditions imply that

$$b'_{c_i} - \lambda_p\, p_i^* = 0 \quad \text{for } i = 2,..,n, \tag{12}$$

where λ_p denotes the marginal utility of income for the household and p_i^* denotes the consumer price of good i.

Free entry and profit maximizing firms implies that sales revenues, given by the producer price, q_i, multiplied by production, αl_i, minus wage costs, given by the wage rate, w , multiplied with labor input, l_i, equals zero.

$$q_i\alpha l_i - wl_i = 0, \text{ for } i = 1,\dots,n \tag{13}$$

Hence, the producer price is determined by the wage rate and labor productivity, $q_i = \frac{w}{\alpha}$, and consumer prices are given by the producer price, q_i, plus the additive consumer tax rate, t_i, i.e. $p_i = q_i + t_i$, for $i = 1,\dots,n$. Labor is chosen as a numeraire which is not taxed. Hence, producer prices are fixed. It is also assumed that producer prices are identical within the rich and the poor country, and that tax rates on clean goods within the poor country are equalized.

4.2. Taxation

The allocation of consumer goods in the market solution is determined so that

$$\frac{u'_{x_1}}{u'_{x_i}} = \frac{p_1}{p_i} = \frac{q_1+t_1}{q_i+t_i} = 1 + \frac{t_1-t_i}{p_i} \text{ for } i = 2, \dots, n. \quad (14)$$

Equation (8), (9), (12) and (14) implies that the social planner solution is implemented when

$$\frac{t_1-t_i}{p_i} = \frac{\psi e'_{x_1}}{\varphi b'_{c_i}} \quad (15)$$

and

$$t_i = t_j \text{ for } i = 2, \dots, n \text{ and } j = 2, \dots, n. \quad (16)$$

Equation (15) implies that the number of clean goods required to pay for the additional tax on the polluting good, $\frac{t_1-t_i}{p_i}$, equals the damage of an additional polluting good measured in units of clean goods based on the welfare function of the rich country, $\frac{\psi e'_{x_1}}{\varphi b'_{c_i}}$. Equation (16) implies that tax rates on clean goods are equalized.

The Pigouvian tax rate is defined as the marginal damage of pollution measured in money. The marginal damage of pollution measured in money equals the marginal damage of pollution measured in units of clean goods evaluated by households in the poor country multiplied with the price of clean goods, i.e. $\frac{p_i e'_{x_1}}{b'_{c_i}}$. Multiplying equation (15) by the price of clean goods uncover that the additional tax on the polluting good, $t_1 - t_i$, equals the Pigouvian tax when the welfare weight on economic well-being, φ, equals the welfare weight on pollution, ψ. Implementing this Pigouvian tax rate is not sufficient to implement the social planner solution, however. Implementation of the social planner solution requires a tax system with identical tax rates on all clean goods, equation (16), combined with an additional tax on polluting goods designed so that the number of clean goods required to pay for the additional tax equals the marginal damage of pollution measured in units of clean goods. Note that a reduction in altruistic welfare weights will ceteris paribus increase the marginal utility of income within the poor country as foreign aid is reduced. A higher marginal utility of income in the poor country contributes to lower the marginal damage of pollution measured in units of clean goods by households in the poor country. Hence, reduced altruistic welfare weights contributes to lower the Pigouvian tax on emissions via this channel.

The marginal damage of pollution measured in units of clean goods by the government in the rich country, $\frac{\psi e'_{x_1}}{\varphi b'_{c_i}}$, the right-hand side of equation (15), exceeds the marginal damage of pollution measured in units of clean goods by households in the poor country, $\frac{e'_{x_1}}{b'_{c_i}}$, when the welfare weight on pollution exceeds the welfare weight on economic well-being, i.e. when $\psi > \varphi$. Hence, the number of clean goods required to pay for the additional tax on the polluting good, the left-hand side of equation (15), exceeds marginal damage of pollution measured in units of clean goods by households in the poor country in this case. The additional tax on the polluting good consequently exceeds the Pigouvian tax when the welfare weight on pollution, ψ, exceeds the welfare weight on economic well-being, φ.

Choosing a clean good as a numeraire and setting the tax rate on this good equal to zero implies that the tax rate on all clean goods equals zero according to equation (16). The tax rate on the polluting good, equation (15), where p_i equals one, implies that $t_1 = \frac{\psi e'_{x_1}}{\varphi b'_{c_i}}$. A zero-tax rate on the polluting good, if chosen as numeraire, implies that the tax rate on all clean goods is determined by $\frac{-t_i}{p_i} = \frac{\psi e'_{x_1}}{\varphi b'_{c_i}}$, i.e. as a subsidy which equals the marginal damage measured in units of clean goods. Hence, tax formulas presented in equations (15) and (16) hold with both clean and the polluting good as a numeraire.

5. Second-best optimal taxation

The literature on optimal taxation shows that a Pigouvian tax is optimal given a specific set of assumptions, see Kaplow (2012), Jacobs and de Mooij (2015) and Jacobs and van der Ploeg (2019). Another strand of the literature shows that environmental taxes should be designed partly to raise tax revenue and partly to correct for externalities, see e.g. Sandmo (1975) and Bovenberg and de Mooij (1994). The approach in Sandmo (1975) is adopted to illuminate on cases where environmental taxes are also designed to raise tax revenue, i.e. where assumptions that support the Pigouvian tax is not satisfied.

Tax rates on consumer goods are set to satisfy the public budget constraint. The tax rate on labor income is set equal to zero as labor is chosen as numeraire. Hence, the household income within the rich country, y_r, equals the pre-tax wage income, wL. The government budget constraint per representative household is

$$t_1x_1 + .. + t_nx_n = T + S. \tag{17}$$

Tax revenue from taxation of consumer goods consumed by the representative household in the rich country, the left-hand side of equation (17), equals a fixed tax revenue requirement per household in the rich country, T, plus foreign aid per household in the rich country, S. Assuming that the number of households within the rich country equals the number of households within the poor country implies that aid per household in the rich country equals aid per household in the poor country. Assuming a fixed tax revenue requirement is consistent with financing a fixed number of public employees at a fixed normalized wage rate. The indirect utility for the representative household within the rich and the poor country are given as

$$v(P, y_r) = u(x_1(P, y_r), .., x_n(P, y_r)) \tag{18}$$

and

$$g(Q, y_p) = b(c_2(Q, y_p), .., c_n(Q, y_p)) - e(x_1(P, y_r)), \tag{19}$$

respectively. P and Q denotes the consumer price vector within the rich and the poor country, respectively. Following the approach in Sandmo (1975), it is assumed that the cross-price elasticities and the income elasticities equal zero for goods 1 to j. The endogenous choice of leisure is omitted from the utility functions to simplify the presentation. The government maximization problem is

$$\underset{t_1,..,t_n,S}{\text{Max}} v(q + t_1,..,q + t_n, wL) + \varphi g(p_2^*,..,p_n^*, Y^* + S) - \psi e\big(x_1(q + t_1)\big) \quad (20)$$

Given the government budget constraint

$$t_1 x_1(q + t_1) + .. + t_j x_j(q + t_i) + t_{j+1} x_{j+1}(P, wL) + .. + t_n x_n(P, wL) = T + S \quad (21)$$

Y^* denotes a fixed income for the household within the poor country. The price on consumer goods in the poor country, p_i^*, includes a tax, t_i^*. Benefits of public sector services within the poor country financed by taxes on consumer goods is excluded from the welfare function. This assumption is relevant for cases where a dictator confiscates all tax revenues. First order conditions w.r.t. good 1 to j and transfer S combined with the definitions $\frac{\partial v}{\partial y_r} = \lambda_r$, $\frac{\partial g}{\partial y_p} = \lambda_p$, $\theta_i = \frac{t_i}{p_i}$, $\mu = \frac{-\lambda_1}{\beta}$ and Roy's identity implies that

$$\theta_1 = (1 - \mu)\frac{(-1)}{\frac{\partial x_1 p_1}{\partial p_1 x_1}} + \mu \frac{\psi e'_{x_1}}{\lambda_r p_1} \quad (22)$$

and

$$\theta_i = (1 - \mu)\frac{(-1)}{\frac{\partial x_i p_i}{\partial p_i x_i}} \quad \text{for } i = 2,..,j \quad (23)$$

according to appendix B. Assuming that

$$\frac{(-1)}{\frac{\partial x_1 p_1}{\partial p_1 x_1}} = \frac{(-1)}{\frac{\partial x_i p_i}{\partial p_i x_i}} \equiv R \quad (24)$$

combined with equation (22) and (23) and the first order condition for foreign aid, Appendix B, implies that

$$\frac{t_1 - t_i}{(q + t_i)} = \frac{\psi e'_{x_1}}{\varphi \lambda_p q}. \quad (25)$$

First order conditions for households in polluted countries, equation (12), implies that

$$\varphi \lambda_p q = \frac{1}{\left(1 + \frac{t_i^*}{q}\right)} \varphi b'_{c_i}. \quad (26)$$

Inserting equation (26) into equation (25) implies that

$$\frac{t_1 - t_i}{(q + t_i)} = \frac{\psi e'_{x_1}}{\varphi b'_{c_i}} \left(1 + \frac{t_i^*}{q}\right) \tag{27}$$

Hence, the second-best optimal additional environmental tax measured in units of clean goods equals the marginal damage measured in clean goods if altruism is pure and goods are not taxed within the poor aid-receiving country. The second-best optimal additional tax on the polluting good implements the first-best social planner solution in this case because the government is able to raise tax revenue spent on foreign aid while simultaneously adjusting the additional tax on emissions. Hence, the government is able to adjust the tax system to harvest the welfare gain of both emission reductions and foreign aid as both these gains are scaled by the same welfare weight. This explains why the second-best optimal additional tax on polluting goods is not adjusted for the marginal cost of public funds in this case, see Sandmo (1975). The second-best optimal additional environmental tax exceeds the marginal damage if clean goods are taxed within the poor country, i.e. if $t_i^* > 0$, and/or the welfare weight attached to damage exceeds the welfare weight attached to economic well-being within the poor country. The second-best optimal additional tax measured in money is found by multiplying equation (27) with the consumer price of clean goods. This second-best additional tax equals the marginal damage measured in money if altruism is pure and goods are not taxed within the poor aid-receiving country. The second-best additional tax exceeds the marginal damage measured in money if clean goods are taxed within the poor country, i.e. if $t_i^* > 0$, and/or the welfare weight attached to damage exceeds the welfare weight attached to economic well-being within the poor country. Hence, the second-best optimal additional tax on the polluting good is adjusted to raise tax revenue when goods are taxed in the poor country and/or when altruism favors the climate. Note that taxes on goods in the poor country contributes to increase prices. Higher prices contribute to lower consumption and increase the marginal utility of goods as foreign aid is adjusted so that the welfare gain of aid equals the value of public funds. The increase in the marginal utility of goods within the poor country contributes to lower the marginal damage of pollution measured in units of clean goods. Hence, taxes on goods in the poor country contributes to lower the second-best optimal additional tax on the polluting good via this channel.

6. Caveats

Results presented above require that the value of public funds within the donating country equals the welfare gain of additional foreign aid, and that this gain equals the welfare adjusted marginal utility of money within the aid-receiving country. There are several cases where the value of public funds within rich countries exceeds this gain, and hence, where foreign aid is reduced to zero. Such values of public funds imply that the optimal additional tax on the polluting good is reduced compared to the optimal carbon tax within both the social-planner case and the second-best optimal case. Hence, incentives to implement climate policies due to altruistic preferences towards households within poor low-temperature countries are weakened in this case.

One apparent case is countries without extreme poverty, i.e. rich countries that are damage by global warming. The marginal utility of money within such countries are sufficiently low as households are sufficiently rich. The value of public funds within aid-donating countries will exceed the welfare adjusted marginal utility of money within such countries. Optimal foreign aid equals zero in such cases, which fits nicely with observed patterns of foreign aid.

Another case is where the marginal utility of money within aid-receiving countries deviates from the gain of additional foreign aid. One may e.g. argue that the value of public funds within donating countries exceeds the welfare gain of foreign aid which ends up in the pocket of a dictator. The calculations above shows that the second-best optimal additional environmental tax exceeds the marginal damage within the poor aid-receiving country if clean goods are taxed within the aid-receiving country. Hence, incentives to tax emissions within the rich country is sufficient in this case.

A third case is where compensation for environmental damages awarded to poor countries, as agreed upon at COP28, exceeds the desired level of foreign aid. Reduced foreign aid which increases the marginal utility of money within receiving countries contributes to lower the damage of pollution measured in units of clean goods. Reduced aid which lowers the damage of pollution may consequently contribute to lower damage awarded in the future and reduce carbon taxes that are related to the marginal damage of pollution. Hence, reduced foreign aid constitutes a win-win for donating countries in this case. The value of public funds within donating countries may exceeds the welfare gain of foreign aid in this case.

A fourth case is where foreign aid to one poor country does not reduce extreme poverty within other countries that are also damaged by emissions. The marginal damage of emission measured in units of clean goods within these countries are not affected by foreign aid. Hence, the value of public funds within donating countries deviates from the welfare gain of foreign aid in this case. This case violates a key assumption within the model framework of the present study. This key assumption is not violated if foreign aid is allocated to equalize the welfare gain of additional aid among the poor countries, however. Assuming that donating countries allocate their foreign aid to implement this outcome seems to be fairly reasonable.

Finally, foreign aid is arguably a public good, where a donation from a country benefits all rich countries with altruistic preferences for individuals in extremely poor countries. Such benefits to other rich countries are not taken into consideration by donating countries within the present study. The lack of coordinated efforts to combat both global warming and poverty might lead to under provision of emission reductions and foreign aid in a global perspective. The outcome within coordinated solutions is beyond the scope of the present study, however. The aim of the present study is to illuminate on each countries' incentive to tax emissions within uncoordinated solutions when foreign aid is taken into consideration.

7. Conclusion

International climate agreements are hampered by free-riding and self-serving countries. Efforts have been made to strengthen coordination. The success on a global scale has been limited, however. Hence, research aimed at avoiding the free-rider problem associated with global warming policies are crucial. The present study contributes by calculating optimal environmental taxes on commodities within rich countries with altruistic preferences towards households within poor countries when damage inflicted upon poor countries are combined with foreign aid. The article shows that a Pigouvian tax within the rich country which equals the marginal damage inflicted on the poor country implements the social planner solution when altruism is pure. The article further shows that the carbon tax exceeds the marginal damage in the case with paternalistic preferences in favor the climate. The article finally identifies conditions where the second-best optimal additional tax on polluting goods exceeds the Pigouvian tax due to revenue raising. Hence, the study shows that altruistic preferences for households in poor countries which receives foreign aid contributes to solve the free-rider problem associated with damage of global warming inflicted on poor aid-receiving countries. These results are based on a stylized theoretical model and should therefore not be used for policy purposes without careful reflection.

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Appendix A

The Lagrangian is

$$L = u(\alpha l_1, \alpha l_2 - c_2, \dots, \alpha l_n - c_n) + \varphi b(c_2, \dots, c_n) - \psi e(\alpha l_1) - \gamma(l_1 + \dots + l_n - \bar{L}) \qquad \text{(A1)}$$

Foc

$$\frac{\partial L}{\partial l_1} = u'_{x_1}\alpha - \psi e'_{x_1}\alpha - \gamma = 0, \qquad \text{(A2)}$$

$$\frac{\partial L}{\partial l_i} = u'_{x_i}\alpha - \gamma = 0, \quad \text{for } i = 2, \dots, n \qquad \text{(A3)}$$

$$\frac{\partial L}{\partial c_i} = -u'_{x_i} + \varphi b'_{c_i} = 0, \quad \text{for } i = 2, \dots, n \qquad \text{(A4)}$$

$$\frac{\partial L}{\partial \gamma} = 0 \text{ implies that } l_1 + \dots + l_n = \bar{L} \qquad \text{(A5)}$$

Foc implies that

$$\frac{u'_{x_1}}{u'_{x_i}} - \frac{\psi e'_{x_1}}{u'_{x_i}} = 1 \text{ for } i = 2, \dots, n \qquad \text{(A6)}$$

$$\frac{u'_{x_j}}{u'_{x_i}} = 1 \text{ for } i = 2, \dots, n \text{ and } j = 2, \dots, n \qquad \text{(A7)}$$

$$u'_{x_i} = \varphi b'_{c_i}, \text{ for } i = 2, \dots, n \qquad \text{(A8)}$$

Hence,

$$\frac{u'_{x_1}}{u'_{x_i}} - \frac{\psi e'_{x_1}}{\varphi b'_{c_i}} = 1 \text{ for } i = 2, \dots, n, \qquad \text{(A9)}$$

and

$$\frac{u'_{x_j}}{u'_{x_i}} = \frac{b'_{c_j}}{b'_{c_i}} \text{ for } i = 2, \dots, n \text{ and } j = 2, \dots, n. \qquad \text{(A10)}$$

Appendix B

The lagrangian is

$$L = v(q + t_1, .., q + t_n, w\bar{L}) + \varphi g(p_2^*, .., p_n^*, Y^* + S) - \psi e\big(x_1(q + t_1)\big)$$

$$-\beta\big[t_1 x_1(q + t_1) + .. + t_j x_j(q + t_i) + t_{j+1} x_{j+1}(P, wL) + .. + t_n x_n(P, wL) - T - S\big] \qquad \text{(B1)}$$

First order conditions w.r.t. good 1 to i and transfer S is

$$\frac{\partial L}{\partial t_1} = \frac{\partial v}{\partial p_1} - \psi e'_{x_1} \frac{\partial x_1}{\partial p_1} - \beta\left[x_1 + \frac{\partial x_1}{\partial p_1} t_1\right] = 0, \qquad \text{(B2)}$$

$$\frac{\partial L}{\partial t_i} = \frac{\partial v}{\partial p_i} - \beta\left[x_i + \frac{\partial x_i}{\partial p_i} t_i\right] = 0, \qquad \text{(B3)}$$

$$\frac{\partial L}{\partial S} = \varphi \frac{\partial g}{\partial Y_p} + \beta = 0, \qquad \text{(B4)}$$

$\frac{\partial L}{\partial \beta} = 0$ implies that

$$t_1 x_1(q + t_1) + .. + t_i x_i(q + t_i) + t_{i+1} x_{i+1}(P, wL) + .. + t_n x_n(P, wL) = T + S \qquad \text{(B5)}$$

The definitions $\frac{\partial v}{\partial y_r} = \lambda_r$, $\frac{\partial g}{\partial y_p} = \lambda_p$, $\theta_i = \frac{t_i}{p_i}$ and $\mu = \frac{-\lambda_1}{\beta}$ and Roy's

identity implies that

$$\theta_1 = (1 - \mu)\frac{(-1)}{\frac{\partial x_1 p_1}{\partial p_1 x_1}} + \mu \frac{\psi e'_{x_1}}{\lambda_r p_1} \qquad \text{(B6)}$$

$$\theta_i = (1 - \mu)\frac{(-1)}{\frac{\partial x_i p_i}{\partial p_i x_i}} \qquad \text{(B7)}$$