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Abstract

This paper develops a Kantian equilibrium framework, subsuming the global pollution model with private ownership, wherein agents condition their contributions on a universalizable moral imperative reflecting income and preference heterogeneity. After showing a specific proportionality assumption linking Kantian reasoning to other agents' behavior that must make the Kantian equilibrium coincide with the Lindahl equilibrium, we show that the level of the public good increases with income inequality. Applying this framework to a global pollution model, we demonstrate that the Lindahl allocation in the global pollution model may fail to Pareto dominate the voluntary contribution (disagreement) equilibrium. In the global public good problem, we compare the Lindahl allocation with other proposed solutions, so we will discuss the nature of inter-country transfers and whether it Pareto dominates the disagreement equilibrium. Our analysis contributes to a re-interpretation of the morally grounded mechanisms for global public good provision, offering a bridge between normative ethics and economic design.

Keywords: Global externalities, Kantian equilibrium, Income inequality, International emissions trading

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1 Introduction

The provision of global public goods — particularly climate stability — poses persistent challenges at the intersection of equity, efficiency, and international cooperation. Classical approaches grounded in Lindahl (1919) pricing, voluntary contribution mechanisms (disagreement equilibrium in the pollution game), and Pigouvian taxation have each provided partial solutions. Yet the deeper ethical and strategic dimensions of global public good provision remain under-explored, particularly in light of international income inequality and heterogeneity in preferences.

Nishimura (2008) deepened Uzawa's (2003) work. Uzawa (2003) emphasized the use of the application of the neoclassical model to the issue of climate changes, whereas Nishimura (2008) formulated such models as multi-stage game of international negotiations on the level of global pollution. In Nishimura (2008), the Lindahl solution determines the distribution of the pollution permits with unanimous agreement.

This paper simplifies the feature of the multi-stage game, and this paper adds a Kantian equilibrium framework by Roemer (2010) and Roemer and Silvestre (2023) that embeds behavioral codes into strategic behavior by positing that agents choose their contributions according to a universalizable moral imperative. This imperative reflects both income differences and preference heterogeneity, offering a morally grounded rationale for cooperative behavior in the absence of centralized enforcement. Our framework generalizes standard public good models by nesting the Lindahl equilibrium within a Kantian logic of proportionality, whereby each agent internalizes not only the marginal benefit of the public good but also how their behavior should scale if adopted by all others.

A specific proportionality condition linking agents' expectations of others' behavior to differences in income and preferences, the Kantian equilibrium coincides with the Lindahl equilibrium. However, through this equivalence, we show that we have counterintuitive implications: we show that in such a setting, the level of public good provision increases with income inequality — a result that does not have an immediate intuition.

We apply this framework to a global climate model with private ownership and demonstrate several key findings. First, the Lindahl allocation derived in Uzawa (2003) does not Pareto dominate the disagreement equilibrium, echoing results in Nishimura (2008). Second, we confirm that even Pareto-efficient allocations without monetary transfers may leave some countries worse off compared to disagreement, suggesting fundamental limits to purely decentralized or efficiency-based solutions.

These findings critically engage with the Global Public Good Purchasing (GPGP) framework proposed by Bradford (2007) and extended by Guesnerie (2007), and we link the features of international transfers in an allocation proposed by Chander and Tulkens (19997) to international environmental agreements to be politically feasible.

In light of this, our results suggest a reinterpretation of Lindahl's (1919) justice and Roemer's (2010) reciprocity in international public finance: although morally appealing, decentralized mechanisms based on universalizable ethics may underperform in delivering equitable and cooperative outcomes without explicit redistribution. This is in line with with recent critiques (e.g., Buchholz and Rübbelke, 2023).

By integrating ethical reasoning, income heterogeneity, and strategic substitutability, our Kantian equilibrium framework contributes to bridging normative ethics and mechanism design in the context of global public goods. The analysis reinforces the view that redistribution is not merely a fairness criterion but a necessary condition for the effectiveness and legitimacy of international cooperation on global externalities.

2 Model

Consider a simple economy consisting of two groups of countries, —South (group 1) and North (group 2)— where the North is both wealthier and places a higher valuation on environmental quality as a global public good. Intrinsically, a representative citizen in each group of the countries has identical utility functions, but the preference towards the global public good is contingent on the circumstance — which is shaped by income level. The total number of the countries is $n > 1$ with n_1 northern countries and $n_2 = n - n_1$ southern countries.

Suppose that, with respect to private good x_i and public good G, the utility function of a citizen in country i is $u_i = \min\{(1-\alpha_1)\ln x_i + \alpha_1 \ln G, \ (1-\alpha_2)\ln x_i + \alpha_2 \ln G\}$ with $0 < \alpha_1 < 0.5 < \alpha_2 < 1$. In other words, $u_i = (1-\alpha_1)\ln x_i + \alpha_1 \ln G$ when $x_i < G$, whereas $u_i = (1-\alpha_2)\ln x_i + \alpha_2 \ln G$ with greater marginal rate of substitution between G and x_i if $G < x_i$. We assume that

$$n\alpha_1 < 1 - \alpha_1 \tag{1}$$

Namely, once an agent is sufficiently poor to choose $x_i < G$ in the Kantian scheme we describe below, then the valuation of the public by such agents is very low.

A citizen in each country in Southern countries has a mass normalized to 1 and has per-capita income $W - \Delta \equiv W_1 > 0$, and a citizen in Northern countries has a mass normalized to 1 and has per-capita income $W + \frac{n_1}{n_2}\Delta \equiv W_2$ for $\Delta > 0$. The resource constraint is:

$$n_1 x_1 + n_2 x_2 + G = nW. \tag{2}$$

When the resource allocation satisfies $x_1 < G < x_2$ due to inequality of income, the Samuelson condition is:

$$n_1 \frac{\alpha_1}{1-\alpha_1} x_1 + n_2 \frac{\alpha_2}{1-\alpha_2} x_2 = G. \tag{3}$$

2.1 An illustrative case: global climate changes

The countries involve in production defined as $f_i(y_i) = y_i + m_i$, where air pollution y_i as an input. $m_i > 0$ is an exogenous variable that represents rent (excess profit) from production. This function approximates a concave production function.

The feasibility of allocations is devined by $n_1 x_1 + n_2 x_2 = n_1 f_1(y_1) + n_2 f_2(y_2)$. The adoption of this formulation is simply for a purpose of synthesized illustration. $G = \widetilde{G} - (n_1 y_1 + n_2 y_2)$ so that pollution is a pure public bad. Consistent with conventional environmental-economics model, we asssume that the technology f_i is owned privately by agent i. We have $n_1 x_1 + n_2 x_2 + G = \widetilde{G} + n_1 m_1 + n_2 m_2$, which is similar to (2) with the existence of the initial level of the public good $\widetilde{G}$.

3 Lindahl-Kantian equilibrium in North-South framework

3.1 Lindahl equilibrium in climate problem and public-good

We first discuss the case of the last subsection with air pollution. Lindahl equilibrium by Uzawa (2003) is defined as follows: $x_i = f_i(y_i^*) + p(\theta_i Y - y_i^*)$ (θ_i is a variable such that $n_1\theta_1 + n_2\theta_2 = 1$ which is an ownership of the polluting right $Y = n_1 y_1 + n_2 y_2$.

Optimization in production results in $f_i'(y_i^*) = p$ which is equal to 1 in this specific case for illustrative purpose, so that the above budget constraint is equivalent to $x_i - \theta_i Y = m_i$ where the excess profit (a rent) remains as a source of inequality. If the *initial tradable permits* satisfies $n_1\theta_1 + n_2\theta_2 = 1$, then

Definition 1. Uzawa's *Lindahl equilibrium with tradable permits*: θ_i is determined by $\frac{\partial u_i/\partial G}{\partial u_i/\partial x_i} = \theta_i$ subject to $x_i - \theta_i Y = m_i$ and $Y_1^L = Y_2^L$.

Uzawa gave the meaning of the share of the permits θ_i as the willingness to pay for the pollution reduction. As such, this Lindahl allocation generates the transfer $\theta_i Y^L - y_i^*$ by permit trading satisfies the Samuelson condition.

Suppose that Δ is sufficiently high and we suppose that the Lindahl equilibirum with superscript L satisfies $x_1^L < G^L < x_2^L$ (see the complete description in the Appendix).

Definition 2. Lindahl equilibrium for the public-good problem: the representative citizens maximize the utility subject to $x_i + p_i G = W_i$ and (p_1, p_2) such that $n_1 p_1 + n_2 p_2 = 1$ generates the utility-maximizing level $G_1^L = G_2^L$.

The assumption of $x_1^L < G^L < x_2^L$ generates $x_i^L = (1 - \alpha_i) W_i$ so (3) is rearranged to, for $n_1 \alpha_1 + n_2 \alpha_2 = \overline{\alpha}$:

$$n_1 \alpha_1 (W - \Delta) + n_2 \alpha_2 (W + \frac{n_1}{n_2} \Delta) = \overline{\alpha} W + n_1 (\alpha_2 - \alpha_1) \Delta = G^L, \tag{4}$$

which also satisfies the resource constraint (2) and we assume such G^L is on $[(1 - \alpha_1)(W - \Delta), (1 - \alpha_2)(W + \frac{n_1}{n_2} \Delta)]$. Notably, this assumption is satisfied when α_1 and α_2 are not different, n_1 / n_2 is large, and Δ is large. Apparently, the same description is applicable to Definition 1.

In contrast, G in the disagreement equilibrium (next section) where the contribution is made voluntarily by the North is $\hat{G} = \frac{1}{1 + \frac{1}{n_2}} (W + \frac{n_1}{n_2} \Delta)$, with $\hat{x}_2 = \frac{1}{1 + \frac{1}{n_2}} (W + \frac{n_1}{n_2} \Delta)$ as a post-contribution income of the Northern citizens, and $\hat{x}_1 = W - \Delta$. As known by Buchholz and Rübbelke (2023), the disagreement equilibrium in the global-climate model may provide more public good or greater u_1 to Southern citizens than in the Lindahl equilibrium.

3.2 Kantian structure with North-South economy

In contrast, we now consider the Kantian equilibrium that applies to the individual budget constraint $x_i + g_i = W_i$ in the pubic-good economy and $x_i = \hat{y}_i - g_i + m_i \equiv W_i - g_i$ in the air-pollution model where the countries voluntarily reduce the pollution from its disagreement-equilibrium level $\hat{y}_i$.

Definition 3. Given β_1 and β_2, consider the following utility $V_i(g_i) \equiv u_i(W_i - g_i, n_i g_i + n_j \beta_i g_i)$ for $j \neq i$. A strategy (g_1^K, g_2^K) consists of Kantian equilibrium with (β_1, β_2) if g_i^K maximizes $V_i(g_i)$ and $\beta_i g_i = g_j$ for $i = 1,\ 2$ and $j \neq i$.

Here we formulate Kantian moral reasoning, i.e., "what if everyone acted as I do" as follows: (i) every Southern (Northern) citizen behaves symmetrically; (ii) every Southern citizen has "as if" behavior for Northern citizen based on different conditional preference for the public good and different income; every Northern citizen has similar "as if" behavior for Southern citizens; (iii) the Kantian type of cooperative behavior is formulated as the utility-maximizing contribution to the public good.

The first-order condition of optimality given β_i is as follows:

$$\frac{dV_i}{dg_i} \propto -G + n_i \frac{\alpha_i}{1-\alpha_i} x_i + n_j \frac{\alpha_i}{1-\alpha_i} x_i \beta_j = 0. \tag{5}$$

The second term in the middle corresponds to the gain through coordinated contribution of g_i among citizens with the same circumstance, and in the last part, Southern citizens think of the suitable proportional behavior to the wealthier and a more public-good preferring citizens ($\alpha_2 > \alpha_1$), conditional on their wealth. A symmetric explanation applies to β_2.

Proposition 1. (i) In this economy, if we set the coefficient $\beta_i = \frac{\alpha_j}{\alpha_i} \frac{W_j}{W_i}$ and hence the agent i expect an agent with different circumstance to behave as $g_j = \frac{\alpha_j}{\alpha_i} \frac{W_j}{W_i} g_i$ as Kantian imperative, then the Kantian equilibrium coincides with the Lindahl equilibrium. Namely, the assumption is that each agent contributes according to income and the preference, with the latter being income-dependent in the present scenario.

(ii) In this Kantian=Lindahl allocation, the level of the public good is greater when the inequality of income represented by Δ is greater.

(iii) Uzawa's (2003) Lindahl mechanism does *not* Pareto dominate the disagreement equilibrium.

For the proof and significance of part (iii), see the next section.

In a Cobb–Douglas economy used for illustration, we impose a plausible Kantian structure of moral universalizability in which agents contribute more according to income (or, in an environmental economics variant, production technology) and preferences, yet the resulting allocation remains Pareto efficient.

However, this rule indicates that the provision of the public good declines as income becomes more equally distributed. Our results highlight key features underlying Lindahl (1919) conception of justice and notion of reciprocity by Roemer (2010) and Roemer and Silvestre (2023). Both frameworks envision the announcement of individual contributions in a decentralized setting, where such announcements are shaped by mutual interaction — specifically, through the strategic substitutability of individual contributions.

In our formulation of Kantian ethics, where contributions are proportional to income or a circumstance-contingent preference, a paradox emerges: if richer countries are more concerned about the global environment and direct resources toward poorer, less environmentally concerned countries (with this concern arising solely from income differences, as agents share identical preferences), the outcome may ultimately harm the environment more. This is because redistribution in such a setting can reduce the aggregate level of public good provision.

4 Global public good

In the global climate model, Bradford (2007) and Guesnerie (2007) both investigate mechanisms for the provision and financing of global public goods (GPGs), such as climate stability. Their proposal on Global Public Good Purchasing (GPGP), amending a Kantian approach and Lindahl pricing, sorrounds the following two points:

1. Redistribution for Participation and Equity:

   Their central theme is the need for redistribution to render participation in international environmental agreements politically and economically acceptable for all countries. Refinement of this argument by Murty (2007) is particularly relevant. She distinguishes two components: Pigouvian pricing (to internalize externalities) and equity (income redistribution). In Murty (2007), G is purchased centrally rather than the Lindahl=Kant manner.

2. Voluntary Cooperation Under Political Constraints:

   The works by Buchholz and Rübbelke (2023) and others are relevant which point out that voluntary contribution equilibrium (referred to as the disagreement equilibrium in the global climate model) may provide more public good than in the Lindahl=Kant equilibrium which increases the South's free-riding benefit. Income rectification matters for the inclusion of the South out of the disagreement equilibrium. It may be worthwhile to mention that, since we incorporated the global-pollution model in the nested structure of the current class of the models, the conclusion by Buchholz and Rübbelke (2023) is applicable to Uzawa's (2003) Lindahl mechanism which does *not*, contrary to Uzawa (1999), Pareto dominate the disagreement equilibrium (Proposition 1.(iii)).

Independently, Chander and Tulkens (1997) and Eyckmans (1997) consider core allocations immune to coalitional deviations. Chander and Tulkens' (1997) core subsumes our focus of Pareto domination of the disagreement equilibrium (as a minimum requirement for the proposed allocation). Also, Shiell (2003) paid attention to an efficient allocation under the constraint that no net monetary transfers occur between countries. Their proposals relate to the two points of GPGP mentioned above, which we elaborate in the following:

4.1 Decentralized ownership and Pigouvian cost share

An allocation proposed by Chander and Tulkens (1997) and Eyckmans (1997) is as follows. The disagreement equilibrium is determined by a Nash equilibrium where each agent maximizes $u_i(f_i(y_i), \widetilde{G} - Y_{-i} - y_i)$ given Y_{-i} and $Y = Y_{-1} + y_i$. Let the corresponding Nash equilibrium level of pollution be $\hat{y}_i$ by each agent in Northern or Southern country. Each country adjusts y_i to y_i^*, and x_i is determined $MRS_i \equiv \frac{\partial u_i/\partial G}{\partial u_i/\partial x_i}$:

$$x_i = f_i(\hat{y}_i) - \frac{MRS_i}{n_1 MRS_1 + n_2 MRS_2} \sum_{i=1,2} n_i(f_i(\hat{y}_i) - f_i(y_i^*)) \tag{6}$$

The allocation of y_i^* and $G^* = \widetilde{G} - n_1 y_1^* - n_2 y_2^*$ where each agent maximizes the utility given $r_i \equiv \frac{MRS_i}{n_1 MRS_1 + n_2 MRS_2}$ in (6) resembles the classic ratio equilibrium by Kaneko (1977). Also, such allocation satisfies the following *production efficiency*: for $Y^* = n_1 y_1^* + n_2 y_2^*$,

$$(y_1^*, y_2^*) \text{ minimizes } \sum_{i=1,2} n_i(f_i(\hat{y}_i) - f_i(y_i)) \ s.t. \sum_{i=1,2} n_i y_i = Y^* \tag{7}$$

so Eyckmans (1997) defines the allocation by, denoting $y_i(Y)$ as the production-efficient y_i given Y, $\sum_{i=1,2} n_i(f_i(\hat{y}_i) - f_i(y_i(Y))) \equiv C(Y)$. Hereafter, we call this allocation as the equilibrium *with public ownership of firms*, in contrast to Uzawa (2003) to the equilibrium *with private ownership*. This distinction is an issue in Roemer and Silvestre (2023).

In two-type economy, this allocation satisfies both Pareto efficiency and Pareto domination of the disagreement equilibrium. Nishimura (2008), however, showed that $\hat{y}_i - y_i^*$ may be negative for some country, even though the pollution is reduced in Pareto efficient allocation.

It is also clear that, once we try to correspond to the economy with private ownership with, for example, tradable permit, by $f_i(\hat{y}_i) - r_i \sum_i n_i(f_i(\hat{y}_i) - f_i(y_i^*)) = f_i(y_i^*) + p(\theta_i^{CT} Y - y_i^*)$, then it is clear that no natural restriction allows θ_i^{CT} to be a normal range of $0 < \theta_1^{CT} < 1$. Rather, (6) may be regarded as a centralized purchase of G where the cost-sharing depends on the Pigouvian coefficient r_i and rectification of the resources from the disagreement equilibrium $x_i = f_i(\hat{y}_i)$ that is decomposed by $\hat{y}_i + W_i$ in the current environment.

Proposition 2. In the ratio equilibrium associated with (6):

(i) (Nishimura (2008)) some countries may emit more pollution than under disagreement equilibrium.

(ii) if we consider the tradable-permit scheme, no natural restriction allows θ_i^{CT} to be in $0 < \theta_1^{CT} < 1$.

4.2 Transfers for voluntary cooperation

Shiell (2003) above departs from the standard Lindahl equilibrium, in contrast to Uzawa's (2003) Lindahl allocation, which typically involves redistribution (by $\theta_i Y - y_i$) through reallocation of productive resources. A less widely noted feature of Shiell's allocation is that it does *not* Pareto dominate the disagreement (voluntary contribution) equilibrium, thereby violating this principle of the GPGP framework — namely, the feasibility and desirability of cooperative outcomes (Nishimura (2008)).[1]

Proposition 3. (Nishimura (2008)) In the global pollution model in Section 1.1, the Pareto efficient allocation without monetary transfers does not necessarily Pareto dominate the disagreement equilibrium.

Yang (2008) made "reverse-engineering" argument further implies that the implementation of any Pareto-efficient allocation based on a specified Negishi weighting scheme requires explicit redistribution of resources across countries.[2]

4.3 Incentive compatibility and summary

Bradford (2007) and Guesnerie (2007) also proposed the third principle of Incentive Compatibility. The implementation issue inspired from the Clarke-Groves-Vickrey framework is well-known. Nishimura (2008) showed that Uzawa's (2003) allocations are implementable via a bilateral price mechanism which is a natural application of the standard mechanism-design theory. It seems that the literature surrounds the implemantability of the Lindahl allocation with the addition of incentive taxes. Eyckmans (1997) showed that the ratio equilibrium is implementable.

[1] "In the absence of regulation, the countries will be located below the [Pareto] frontier, ... [T]here is one Pareto-efficient allocation associated with zero transfers ... This point is located to the north-east of [the disagreement equilibrium], since both countries benefit from some level of pollution control, even given the existing imbalance in the distribution of income." (Shiell (2003, pp. 42-43)).

[2] His usage of "Lindahl principle" is different from conventional Lindahl framework since the latter, as shown by Buchholz and Rübbelke (2023) and others, does not necessary Pareto dominate the disagreement equilibrium.

allocations	private ownership	public ownership	no transfers
P.d. of disagreement equil.	No*	Yes	No*
Features of x_i	$(1-\alpha_i)W_i$	W_i is owned by i in (6)	$y_i^* + W_i$
If $x_i = f_i(y_i^*) + (\theta_i Y - y_i^*)$	$0 < \theta_i < 1$	θ_i may not be in $(0,\ 1)$	$\theta_i = \frac{y_i^*}{n_1 y_1^* + n_2 y_2^*} \in (0,1)$
Nash implementation	Yes (Nishimura (2008))	Yes (Eyckmans (1997))	n.a.

Table 1: Lindahl=Kant equilibrium and other solutions. "P.d." means "Pareto domination".

($*$: Uzawa (1999) and Shiell (2003) respectively said "Yes", but Proposition 1 (iii) and Proposition 3 amend to conclude "No")

Appendix

Along the utility possibility frontier, we consider the following way. Consider first $x_1 = x_2 = x^*$ and we consider $\max u_i(x^*, n(W - x^*))$. If $x^* > n(W - x^*)$, agent prefers $\frac{x^*/W}{1-\alpha_2} = \frac{1-\frac{x^*}{W}}{\alpha_2}$ so $x^*/W = 1 - \alpha_2$, which is violated since $\alpha_2 > 0.5$. If $x^* < n(W - x^*)$, agent prefers $\frac{x^*/W}{1-\alpha_1} = \frac{1-\frac{x^*}{W}}{\alpha_1}$ so $x^*/W = 1 - \alpha_1$, which holds if $n\alpha_1 > 1 - \alpha_1$ which we exclude by assumption.

Therefore, the only possibility is $x^* = n(W - x^*)$. If one changes x^* by dx, the utility changes by $(\frac{1-\alpha_i}{x^*} - \frac{\alpha_i}{x^*} n) dx$ with $i = 1$ if $dx < 0$ and $i = 2$ if $dx > 0$. The utility increases in neither direction. This allocation is the Lindahl allocation with $p_i = \frac{1}{n}$ and $W_i = W$, which is Pareto efficient.

Then consider a Pareto efficient allocation that can be supported by a Lindahl allocation with lunm-sum transfers, with x_1^L in the neighborhood of x^* but $u_1(x_1^L, G^L) < u_1(x^*, x^*)$. Clearly we have $x_1^L < G^L$ so $x_1^L = (1 - \alpha_1)(W - \Delta)$ and the Lindahl budget constraint of agent 2 satisfies $x_2 + p_2 G = W + \frac{n_1}{n_2}\Delta$. Since the allocation of (4) does not satisfy $x_1^L \leq x_2^L$ so one ends up with $x_2^L = G^L$

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