# Indirect and direct lobbying on international trade in waste[*]

Miao Dai,[†] Guillaume Cheikbossian[‡]

February 21, 2026

**Abstract**

This paper proposes a micro-founded model to investigate the effects of environmental lobbying on international trade in waste. We first develop a direct lobbying framework à la Grossman and Helpman (1994) that emphasizes the potential impact of green lobbies on the environmental policy and how North-to-South waste flows are affected through this policy channel. We show that the politically chosen policy is ambiguous relative to the socially optimal level, depending on the heterogeneity of environmental preferences and the degree of pollution damages from waste. This in turn leads to ambiguous effects of environmental lobbying on the North-to-South waste trade. Further, we build an indirect lobbying model based on Yu (2005) to analyze the impact of indirect lobbying through public persuasion by interest groups on environmental policy stringency, political contributions and waste exports. We show that strengthening green lobbying induces a complementarity between direct and indirect competition, causing both the environmental and industrial lobby groups to behave less aggressively in their two means of influence. Consequently, this results in a more stringent environmental policy and more waste to be exported. Finally, we demonstrate that an increase in the foreign waste absorption fee intensifies the competition between lobbies in both the indirect and direct lobbying games, ultimately leading to lower volumes of waste exports.

**Keywords:** Trade in waste; Environmental lobbying; Political economy; Externality;
**JEL Codes:** D72, F14, F18, Q53, Q56, Q58

[*]A previous version of this article was circulated under "Environmental Lobbying on International Trade in Waste: Theory and Evidence"(Dai, 2023). This paper is a thoroughly revised and extended version of the theory part of the earlier paper. We are grateful to Jevan Cherniwchan, Valeria Fanghella, and participants at the 13th Annual Conference of the Italian Association of Environmental and Resource Economists (IAERE) and 30th Annual Conference of the European Association of Environmental and Resource Economists (EAERE) for their insightful comments. The authors acknowledge the financial support from the Agence Nationale de la Recherche (ANR GROUP), grant ANR-22-CE26-0014-01. Miao Dai also thanks the Swiss National Science Foundation (SNSF) (Division 1, Grant No. 212632), the Agence Nationale de la Recherche, grant ANR-21-CE03-0012 (ScarCyclET), the Canadian Social Sciences and Humanities Research Council (SSHRC), the Fonds de recherche du Québec - Société et culture (FRQSC) and the Réseau de recherche en économie circulaire du Québec (RRECQ) for their financial support. We declare that we have no conflict of interest. No data were generated or analyzed for this study.

[†]Corresponding author. Department of Spatial Economics, Vrije Universiteit Amsterdam and Tinbergen Institute. Email: miao.dai@mail.mcgill.ca.

[‡]Center for Environmental Economics – Montpellier (CEE-M), University of Montpellier, CNRS, INRAE, Institut Agro Montpellier, France. Email: guillaume.cheikbossian@umontpellier.fr.

# 1 Introduction

Growing waste generation coupled with a highly globalized economy has led to increased volumes of waste being shipped across borders. The global South, in need of employment and foreign exchange offered by the waste trade, has often been targeted by the North as a dumping haven to absorb their excessive waste. However, developing countries are typically ill-equipped to handle the recycling and recovery of material that is often highly toxic. Consequently, much of the waste is dumped or discarded directly into the environment, causing a further escalation of environmental degradation (Kellenberg, 2012; Shi and Zhang, 2023). With the shocking sight of towering waste piles in the neighbourhoods of developing countries and giant garbage patches floating on the ocean, there is widely documented evidence of adverse environmental and public health problems caused by waste.[1]

Galvanized by the growing pace and scale of climate change, environmental lobby groups have increased significantly both in size and strength over the past few decades.[2] Their rising impacts are shaping the political landscape (Wapner, 1995; Fredriksson et al., 2005; Longhofer and Schofer, 2010) and steering government policies towards better environmental outcomes (Kalt and Zupan, 1984; Cropper et al., 1992; Riddel, 2003; Binder and Neumayer, 2005; Fredriksson et al., 2005).

This paper investigates the role of green lobbies in the international waste trade and seeks to understand whether strengthening environmental lobby groups can represent an important strategy to reduce the North-to-South waste trade. To address this question, we first develop a political economy model à la Grossman and Helpman (1994). Using this model, we investigate how green lobbies might affect the determination of environmental policy and how waste trade flows are affected through this policy channel. We focus on a representative small open economy in the North, where waste is modelled as an environmentally harmful byproduct generated during the production process. This byproduct is tolerated at some level and subjected to a pollution tax, and it can be exported to a developing country for disposal but with a fee. Two organized lobby groups – environmentalists and capitalists – with heterogeneous environmental preferences confront the incumbent government with contribution schedules contingent

[1]For example, Trafigura, a Dutch oil trading company with additional offices in Great Britain, dumped hundreds of tons of waste at Abidjan, Côte d'Ivoire (Ivory Coast) in 2006, and caused nausea, headaches, vomiting, violent rashes, and even death among thousands of people living near the dump sites. See https://www.business-humanrights.org/en/latest-news/trafigura-lawsuit-re-hazardous-waste-disposal-in-cÃt'te-divoire-filed-in-the-netherlands/. More recently in 2019, the dragging Canada-Philippines garbage dispute finally came to an end after Canada agreed to take back its trash sent to the Philippines 6 years ago, which was falsely labelled as recyclable scrap but instead contained household waste. Tonnes of rotting refuse have sat festering on the docks of Manila, causing port congestion and posing a health hazard risk. See https://www.nytimes.com/2019/05/23/world/asia/philippines-canada-trash.html.

[2]For instance, up to date, the Environmental Defense Fund has an active membership of 2.5 million with operations in 28 countries and operating expenses reaching a record $216 million in 2020. See https://www.edf.org/about. The other leading environmental NGO, Greenpeace, has also expanded massively with national and regional organizations across the world.

on its waste policy. The government then tries to balance the competing interests of these lobby groups and chooses the policy that maximizes a weighted sum of the social welfare and campaign contributions received from them.

We show that the tax set by the government is ambiguous relative to the socially optimal level, depending on the heterogeneity of environmental preferences and the degree of pollution damages from waste. This political distortion arises from two facts: one is that lobby groups offer campaign contributions to an electorally motivated government in exchange for particular political favours (Aidt, 1998); the other is that lobby groups with heterogeneous environmental attitudes respond differently to various degrees of waste-induced environmental damage. Because of the relatively lower environmental valuations and the additional incentive to reduce the negative policy effect on profits that do not accrue to environmentalists, capitalists will typically lobby more aggressively for a less stringent policy, which eventually dominates any countervailing efforts from environmentalists. The resulting equilibrium policy level will be lower than the socially optimal one. However, if environmental damage caused by waste is significant enough, it will play an increasing role in both lobby groups' welfare calculations, inducing capitalists to diminish their lobbying efforts while triggering a more aggressive response from environmentalists. Consequently, the political equilibrium policy may equal or even overshoot the social optimum.

We then investigate how strengthening green lobbies – as measured by an increase in the number of environmentalists and the joining members' environmental valuation – might affect the policy stringency and by extension firms' decisions on waste trade. This can be interpreted as an environmental movement in which growing environmental awareness has arguably enabled environmentalists to mobilize more ordinary people to join forces and exert pressure on governments to take more action. Our model generates ambiguous predictions about the effects of environmental lobbying on trade in waste.

We show that when capitalists have a dominating lobbying power, which leads to a downward distorted policy that is inefficiently weak, strengthening environmental lobbies will lead to a higher tax and therefore result in more waste being exported. Indeed, as more people become environmentally concerned and join the green lobbying while the number of capitalists is fixed, this translates into more power exercised by the environmental lobby group. As a result, the government will respond to this boosted political pressure by increasing regulations on the externality. This in turn leads to a higher tax in the North, which increases the domestic waste disposal costs and thereby induces firms to export more waste out of the country for disposal. Using a different model, McAusland (2008) draws a similar conclusion, demonstrating that when facing increased political pressure from lobby groups, regulators have an incentive to increase regulation on pollution that is a by-product of consumption activities and thereby induce firms to export waste to locations with lower environmental regulations.

However, in the case of environmentalists lobbying more aggressively while capitalists diminish their lobbying efforts, which leads to an inefficiently strict and upward distorted policy, strengthening green lobbying may unexpectedly lead to a lower tax and result in less North-to-South waste exports. While environmentalists strive to protect the country from environmental damage caused by waste, they also benefit from consumption. When the extra savings from environmental damages cannot compensate for their utility loss from consumption, they would like to exchange some environmental protection for more consumption, which relaxes the policy stringency. As the number of environmental lobbyists increases, the desire for the tradeoff also increases, which further reduces the tax. As the pollution tax decreases, the cost of disposing of waste domestically goes down, and therefore, less waste will be exported abroad. Eventually, when all workers become environmentalists, the equilibrium will equal the socially optimal level, leading to a political internalization of the environmental externality (Aidt, 1998).

So far, we have focused on the direct political contribution channel through which environmental lobbies affect the waste trade. However, as demonstrated in Yu (2005), Connelly et al. (2012) and Bentata and Faure (2015), political contributions from environmental lobby groups are typically much smaller compared to those from industrial ones. The success of green lobbying can thus be largely attributed to its greater effectiveness in public persuasion and the resulting higher public environmental awareness. We thus follow Yu (2005) and model a policy game at the first stage where lobbies engage in indirect political competition by sending messages to workers to influence their subjective beliefs regarding waste-induced environmental damages. In contrast to Yu (2005) where the messages sent by environmental and industrial lobby groups are always strategic substitutes, we show that they can also be strategic complements, depending on the size of the group distribution.

Further, we analyze how an increase in the general public's initial environmental awareness could indirectly and directly affect trade in waste. Using some simple functional forms of the model to demonstrate the mechanism at work, we find that greater public awareness of environmental damage reduces the number of messages sent by both the green and industrial lobby groups, while also decreasing both groups' direct political contributions, leading to a higher tax and more waste exports. That is, the two channels of policy influence are complementary to each other – a major departure from the results obtained in Yu (2005) where an increase in the initial public environmental awareness induces the substitution of direct and indirect competition from both lobby groups. This occurs because when the public is already very sensitive to waste-induced environmental damages, there is less room for lobbies to shape their perception, leading them to be less active in indirect lobbying. Nevertheless, this leads to an increase in the posterior public environmental awareness, which boosts the environmental lobby group's bargaining position with the government and thus reduces its direct political contributions. At the same time, facing less opposition from the green lobbies in the political game while receiving a tax refund for every unit of waste that is being exported, the industrial lobby group can afford to be less aggressive in direct competition, making fewer political contributions as well.

Finally, we investigate how an increase in the foreign waste absorption fee could affect the political outcome. This again leads to a complementary effect between indirect and direct competition in terms of lobbying, since higher foreign waste-treatment costs encourage lobbies to be more aggressive in both of their means of influence, increasing both the number of messages they send and their direct political contributions, which ultimately leads to a decline in waste exports. This is because a higher waste absorption fee makes the domestic environmental policy more decisive both for producers' profits and for the environmental damage, to which the green lobby is more sensitive than the rest of the population, thereby intensifying the competition between the two.

We contribute to several strands of literature. The first concerns the extensive literature on the political economy approach of endogenous trade policy[3] that has been later extended to endogenous environmental policy-making (Fredriksson, 1997; Aidt, 1998; Schleich, 1999; Conconi, 2003; Fredriksson et al., 2005; Fünfgelt and Schulze, 2016; Cassing and Long, 2021). We add to the literature by incorporating heterogeneous environmental preferences and providing some new insights into the politically distorted equilibrium. Our paper is closely related to Cassing and Long (2021), but extends their work in a number of dimensions. First, we supplement their model by including an indirect competition game where lobby groups compete in public persuasion. Second, we provide some new insights about the political economy equilibrium. That is, the politically chosen policy can be even tighter than the socially optimal one if waste-induced environmental damages are large enough. Third, our model enables us to investigate and demonstrate explicitly how lobby groups might affect waste trade both directly and indirectly.[4]

Our research also contributes to the studies that investigate various factors in waste trade. Previous studies have estimated the effects of various economic factors on transboundary waste shipments, including income and capital-labour ratio (Baggs, 2009), recycling cost (Kellenberg, 2012), environmental regulation (Baggs, 2009; Kellenberg, 2012), wage and population (Higashida and Managi, 2014) and Basel Convention (Kellenberg and Levinson, 2014). However, these econometric analyses are built upon the conventional economic line that governments are benevolent in always maximizing social welfare while ignoring other factors such as lobby groups and political contributions (Goldberg and Maggi, 1999; Gawande and Bandyopadhyay, 2000; Pacca et al., 2021). We contribute to this literature by taking the political economy approach and investigating the role of environmental lobby groups in the international waste trade.

Finally, our findings contribute to the policy discussions that aim to reduce transboundary waste shipments. The existing policy approach includes international treaties

[3] See Grossman and Helpman (2020) for a review of the literature.

[4] While Cassing and Long (2021) assume that individuals have heterogeneous environmental preferences within and across different groups, we consider the situation where environmental preference only differs across groups but remains the same within the group. One reason for doing so is that it allows us to analytically investigate the effect of the environmental movement.

such as the Basel Convention, Rotterdam Convention and Stockholm Convention as well as individual countries' own restrictions and environmental regulations.[5] However, ample evidence suggests that these approaches are falling short. Like any other international environmental agreements (IEAs), the above-mentioned treaties also suffer the free-riding problem and some of them are merely seen as an attempt by countries to bolster their international image without active ratification or enforcement. The US, one of the largest waste exporters, has yet to sign any of the agreements. Even though many jurisdictions such as Australia, Canada, the UK and the European Union have ratified them, millions of tonnes of waste are still heading their way to developing countries each year. Using annual bilateral waste shipments among countries before and after one of the trading partners ratifies the Basel Convention, Kellenberg and Levinson (2014) find no evidence that the Convention has resulted in less waste being traded. Note that unlike most of the other transboundary pollution problems such as climate change that need global cooperation, the waste problem arises from the fact that the externality is intentionally and consciously packed and shipped anywhere in the world that is willing to accept it. The deliberate and voluntary nature of these actions raises hope for a possible solution.[6] Our paper contributes to the literature by highlighting the role of political lobbying in the waste trade.

The remainder of the paper is structured as follows. Section 2 presents the theoretical framework of direct lobbying. Section 3 derives the political economy equilibrium tax and Section 4 analyzes the direct effects of environmental lobbying on tax and by extension trade in waste. Section 5 characterizes the equilibrium political contributions. Section 6 extends the model to include indirect competition and investigates how indirect lobbying could affect environmental policy stringency, political contributions and waste exports. Finally, Section 7 concludes.

## 2 The model: Direct lobbying

A small open competitive economy in the North has two sectors. The first one is a clean sector, which produces a numeraire good using labour only with constant returns to scale and a one-to-one input-output ratio. The other is a polluting sector that uses capital and labour to produce a manufacturing output according to the production function $Y = F(K, L)$ that exhibits constant returns to scale with positive and diminishing marginal products and convex isoquants. During the manufacturing process, a negative externality or by-product called "waste" is generated.[7] For simplicity, each unit of

[5]For example, both Canada and the European Union have introduced the extended producer responsibility program, which makes producers accountable for waste disposal costs and responsible for establishing recycling and reuse objectives (Bernard, 2015).

[6]Recently, several papers have looked at the impact of the Chinese waste ban; see, for example, Shi and Zhang (2023); Guo, Walls and Zheng (2023); Sommer (2024); Zhang, Yu and Li (2025).

[7]Alternatively, waste can be modelled as a consumption externality, see e.g., McAusland (2008), but the results do not change qualitatively.

output is accompanied by a unit of waste, denoted by $E = Y$. The North can ship $Q \leq Y$ units of its waste to the South for disposal at a constant unit price $\mu > 0$. For $Q$ units of waste exported, firms incur a cost $\eta(Q)$ in collecting, sorting as well as packaging and transportation of waste, where $\eta(Q)$ is strictly convex with $\eta(0) = 0, \eta'(Q) > 0$ and $\eta''(Q) > 0$.[8] Suppose that the North is endowed with a fixed supply of capital and labour, denoted by $\bar{K}$ and $\bar{L}$, respectively, and that labour is perfectly mobile across sectors and full employment prevails. The domestic and world price of the numeraire good is set equal to one, then the economy-wide wage rate is fixed at $w = 1$. Let $p$ denote the domestic and world price of the manufacturing good, and we assume that free trade prevails in both markets.

The economy is populated by $n$ heterogeneous citizens, each endowed with $\bar{l}$ units of labour, where $\bar{L} = n\bar{l}$. Each individual $i$ derives satisfaction from the consumption of both goods, represented by a quasi-linear utility function: $U_i = x_i + u(y_i)$, where $x_i, y_i$ denote the consumption of numeraire and manufactured goods, respectively, with $u'(\cdot) > 0, u''(\cdot) < 0$. Each individual $i$ also suffers from the pollution caused by waste remaining in the country. The welfare of individual $i$ is thus given by

$$W_i(x_i, y_i, Z) = x_i + u(y_i) - \beta_i D(Z),$$

where $Z = Y - Q$ is the amount of waste or pollution that remains in the country, $D(Z)$ is the damage function with $D(0) = 0, D'(Z) > 0, D''(Z) \geq 0, D'''(Z) \leq 0$, and $\beta_i$ denotes individual $i$'s preference for environmental quality. By denoting $\bar{\beta} = \frac{1}{n}\sum_{i=1}^{n}\beta_i$ as the society's average environmental preference, the social marginal cost of a unit of waste is $\frac{\partial \sum_{i=1}^{n} W_i}{\partial Z} = n\bar{\beta}D'(Z)$.

Suppose the $n$ individuals can be categorized into 3 groups. Group 1 consists of $n_C$ individuals who own capital, referred to as capitalists. For simplicity, all the capitalists are assumed to have the same environmental preference, denoted by $\beta_C \in [0, \bar{\beta}]$, and each of them has an equal endowment of capital, $\bar{K}/n_C$. Group 2 consists of $n_E$ non-capitalists who share the same strong preference for environmental quality, referred to as environmentalists, with $\beta_E \geq \bar{\beta}$. Environmentalists are assumed to only care about local pollution and are not concerned with global issues – referred to as NIMBYs (not in my backyard). Finally, the remaining $n_W$ non-capitalists, referred to as workers, constitute Group 3 with the same moderate preference for environmental quality at $\beta_W \in [\beta_C, \beta_E]$ (without needing to specify whether $\beta_W$ is greater or less than $\bar{\beta}$).

Suppose individuals with similar interests can overcome the free-riding problem (Olson, 1965), and are formed as organized lobby groups to further their interests by taking collective action to influence government policies. In this paper, we only consider two organized lobby groups – capitalists and environmentalists – while workers are not organized.[9] We first adopt the structure of the two-stage common agency game

[8]One can also interpret $\eta(Q)$ as the amount of labour that is required for these activities.

[9]When all groups are organized, the political economy equilibrium tax is efficient and identical to

developed by Bernheim and Whinston (1986) and later employed by Grossman and Helpman (1994) to analyze the politics of trade policy. In the first stage, each organized group simultaneously and non-cooperatively offers to the incumbent government a campaign contribution contingent on the pollution tax selected by the government to correct for the externality. By definition, individuals in an unorganized group do not have enough stake in the policy outcome and thus make no campaign contributions. In the second stage of the game, the government takes the “announced contribution schedules" as given and chooses an environmental tax $t$ on the manufacturing output to maximize a weighted sum of social welfare and campaign contributions:

$$\max_{t} G(t) = \delta J(t) + \sum_{h \in \Lambda} \psi_h(t),$$

where $J(t) = \sum_{i=1}^{n} J_i(t)$ is the aggregate social welfare, $\psi_h(t)$ is the campaign contribution made by lobby group $h \in \Lambda = \{C, E\}$, and $\delta > 0$ is an exogenously given weight that the government attributes to social welfare relative to political contributions.

Finally, the domestic firms will receive a tax refund $t$ for every unit of waste that is being exported, i.e., the government will only tax the pollution that remains within the country. This can be seen as a form of border tax adjustment (Keen and Kotsogiannis, 2014; Cosbey et al., 2020). Another way to interpret this tax refund is that firms will save an equivalent per unit cost of $t$ in administering those exported waste. As for the remaining tax revenue, the government will distribute it as a lump-sum tax transfer to all the individuals in the economy. Refunding environmental charges back to the polluting industry and consumers is quite often and typically reduces resistance from the polluters, making the policy more politically acceptable than a standard tax. See, for example, the refunded emission payment scheme in Sweden (Sterner and Isaksson, 2006), the carbon tax rebate programs in Canada, and other examples in Aidt (2010).

In the following, we solve the problems of firms, consumers, lobby groups and the government, respectively. First, taking as given the world price of the manufactured good $p$, the unit waste absorption fee $\mu$, and the environmental tax $t$ on manufacturing output, which is also the refund per unit of waste exported, each competitive manufacturing firm chooses the input levels $(K_j, L_j)$ and waste export level $(Q_j)$ to maximize its profit:

$$\max_{K_j, L_j, Q_j} \pi_j = (p - t)F(K_j, L_j) - wL_j - rK_j + (t - \mu)Q_j - \eta(Q_j),$$

where $w = 1$ is the wage rate and $r$ is the rental rate. With the constant returns to scale assumption and $\sum_j K_j = \bar{K}$, we know that for the manufacturing industry as a whole, the industry's employment of labour $L$ and waste exports $Q$ must be determined by maximizing the aggregate return to the capital stock. Thus, the firms' problem can be

the Pigouvian tax, see e.g., Aidt (1998), Cassing and Long (2021), etc.

reformulated as

$$\max_{L,Q} \Pi = (p-t)F(\bar{K}, L) - L + (t-\mu)Q - \eta(Q).$$

Assuming an interior solution, the first-order conditions with respect to $Q$ and $L$ are

$$t - \mu = \eta'(Q), \tag{1}$$

and

$$(p-t)F_L(\bar{K}, L) = 1, \tag{2}$$

where $F_L$ denotes the marginal product of labour in manufacturing. Equation (1) says that at the optimal waste export level $\hat{Q}$, the marginal benefit must be equal to the marginal cost of exporting waste. As long as $t > \mu$, firms would want to export waste abroad. Equation (2) says that at the optimal labour allocation $\hat{L}$, the value of the marginal product of labour is equated to the wage rate. Given $\hat{Q}$ and $\hat{L}$, the maximized aggregate return to capital is

$$\hat{\Pi} = (p-t)\hat{Y} - \hat{L} + (t-\mu)\hat{Q} - \eta(\hat{Q}), \quad \text{where } \hat{Y} = F(\bar{K}, \hat{L}).$$

After solving the firms' problem, we now turn to the consumers' problem. Each consumer $i$ is maximizing her utility subject to her budget constraint:

$$\max_{x_i, y_i} [x_i + u(y_i)], \quad s.t. \quad x_i + py_i = M_i,$$

where $M_i$ is the income of consumer $i$. Every consumer in the economy receives income from two sources: first, she supplies her endowment of labour inelastically to the competitive labour market and thus earns the wage income $w\bar{l}$; second, she receives $1/n$ of the government's net tax revenue $t(\hat{Y} - \hat{Q})$ as a lump sum transfer. However, a capitalist has one additional income source from her endowment of capital, which claims $\hat{\Pi}/n_C$. Therefore, the income of a representative non-capitalist, i.e., environmentalist or worker, is given by

$$M_j = \bar{l} + t(\hat{Y} - \hat{Q})/n, \tag{3}$$

while that of a representative capitalist is

$$M_C = \hat{\Pi}/n_C + \bar{l} + t(\hat{Y} - \hat{Q})/n. \tag{4}$$

Utility maximization yields the first order condition:

$$u'(y_i) = p. \tag{5}$$

Thus, the demand for the manufactured good and numeraire good is respectively:

$$\hat{y}_i = (u')^{-1}(p) \equiv \hat{y}(p), \quad \hat{x}_i = M_i - p\hat{y}_i,$$

and the indirect utility function of consumer $i$ is

$$V_i = M_i - p\hat{y}(p) + u(\hat{y}(p)) = M_i + CS(\hat{y}(p)),$$

where $CS(\hat{y}(p)) = u(\hat{y}(p)) - p\hat{y}(p)$ is the consumer surplus with $\frac{dCS(\hat{y}(p))}{dp} = -\hat{y}(p)$. The resulting total welfare level of consumer $i$ is

$$W_i = M_i + CS(\hat{y}(p)) - \beta_i D(\hat{Z}),$$

where $\hat{Z} = \hat{Y} - \hat{Q}$ and $M_i$ is given by equation (3) for a non-capitalist and equation (4) for a capitalist. Therefore, the aggregate welfare of each group can be expressed as

$$\begin{aligned}
J_C(t) &= n_C\left[\hat{\Pi}(t)/n_C + \bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p)\right] - n_C\beta_C D(\hat{Y}(t) - \hat{Q}(t)),\\
J_E(t) &= n_E\left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p)\right] - n_E\beta_E D(\hat{Y}(t) - \hat{Q}(t)),\\
J_W(t) &= n_W\left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p)\right] - n_W\beta_W D(\hat{Y}(t) - \hat{Q}(t)),
\end{aligned}$$

and the aggregate social welfare is

$$J(t) = n\left[\bar{l} + t(\hat{Y}(t) - \hat{Q}(t))/n + CS(p)\right] + \hat{\Pi}(t) - n\bar{\beta}D(\hat{Y}(t) - \hat{Q}(t)), \tag{6}$$

where by definition, $n\bar{\beta} = n_C\beta_C + n_E\beta_E + n_W\beta_W$.

# 3 The equilibrium tax

In this section, we characterize the environmental tax implemented by a government subject to pressure from environmental and industrial lobbies in the political economy equilibrium. However, it is useful to first derive the socially optimal environmental tax in order to have a benchmark.

Without any political considerations, a benevolent government only cares about the aggregate welfare level of its country. Maximizing (6) with respect to $t$ yields the following result:

**Lemma 1.** *The socially optimal or Pigouvian tax is equal to the social marginal cost of waste, i.e.,*

$$t^{SO} = n\bar{\beta}D'(\hat{Z}).$$

*Proof.* See Appendix A. □

We now characterize the political economy equilibrium tax. The incumbent government's action is the unit pollution tax, and the lobby groups' actions are contribution schedules that map each tax policy into a contribution level. The political equilibrium thus consists of a set of feasible contribution functions $(\{\psi_h(t^*)\}_{h\in\Lambda})$ and the environmental tax policy $(t^*)$. Following Bernheim and Whinston (1986), we focus on the interior equilibrium contribution schedules that truthfully reflect the gains expected by the pressure groups such that $\psi_h(t) = J_h(t) - B_h$, where $B_h > 0$ is a constant. Then, $t^*$ must be the solution to the problem

$$\max_t \hat{G}(t) = (1+\delta)\Big[J_C(t) - B_C + J_E(t) - B_E\Big] + \delta J_W(t),$$

or equivalently

$$\max_t \hat{G}(t) = \Big[J_C(t) + J_E(t)\Big] + \delta J(t). \tag{7}$$

We can thus establish the following result:

**Proposition 1.** *The political economy equilibrium tax $t^*$ is implicitly defined as the solution to*

$$\Omega(t) \equiv \left(t - n\bar{\beta}D'(\hat{Z})\right) + \frac{1-\lambda_0}{\delta+\lambda_0}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}\right] = 0, \tag{C1}$$

*where $t^{SO} = n\bar{\beta}D'(\hat{Z})$ denotes the socially optimal or Pigouvian tax, $\lambda_0$ is the fraction of the population that belongs to the organized lobby groups, and $\frac{d\hat{\Pi}}{d\hat{Z}} = \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt} > 0$ with*

$$\frac{d\hat{Z}}{dt} = \frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt} < 0, \quad \frac{d\hat{\Pi}}{dt} = \hat{Q} - \hat{Y} < 0.$$

*Proof.* See Appendix B. □

A direct comparison of this political equilibrium defined in condition (C1) with the benchmark outcome under a benevolent social planner yields:

**Corollary 1.** *If $\beta_W \geq \bar{\beta}$, or $\beta_W < \bar{\beta}$ with $D'(\hat{Z})$ being small enough, then $t^* < t^{SO}$. However, if $\beta_W < \bar{\beta}$ and $D'(\hat{Z})$ is large enough, $t^* \geq t^{SO}$.*

Proposition 1 and Corollary 1 demonstrate that the politically chosen tax on the externality is ambiguous relative to the Pigouvian one, depending on the preference distribution of environmental awareness among groups and the degree of pollution damages caused by waste. When $\beta_W \geq \bar{\beta}$ (i.e., $\beta_C \leq \bar{\beta} \leq \beta_W \leq \beta_E$), this indicates that the society has a disproportionally large number of capitalists or capitalists have an extremely low environmental valuation. In this case, since $D'(\hat{Z}) > 0$ and $\frac{d\hat{\Pi}}{d\hat{Z}} > 0$, we must have $t^* < t^{SO} = n\bar{\beta}D'(\hat{Z})$. That is, the pressure exercised by the lobby groups creates a politically downward distortion of environmental policy that is inefficiently weak. While environmentalists always push for a higher environmental tax, capitalists typically lobby in the opposite direction for a less stringent one. Because of the additional incentive to reduce the negative effect of a higher tax on its profits that do not accrue to environmentalists and the relatively lower valuation of environmental damages, the capitalists will lobby more aggressively for the tax that moves in favor of its direction. As a result, the politically determined tax, when balancing the opposing effects of an organized environmental lobby group and an industry lobby group, will be lower than the Pigouvian one.

However, if instead $\beta_C \leq \beta_W < \bar{\beta} \leq \beta_E$, this means that environmentalists are relatively numerous or have a relatively large environmental awareness. In this case, $(n\beta_W - n\bar{\beta})D'(\hat{Z}) < 0$ and the political equilibrium tax can be lower or higher than the Pigouvian level. Denote $A \equiv (n\beta_W - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}$, then we can rewrite

$$\underbrace{A\frac{d\hat{Z}}{dt}}_{<0} \equiv \underbrace{(n\beta_W - n\bar{\beta})D'(\hat{Z})\frac{d\hat{Z}}{dt}}_{>0} + \underbrace{\frac{d\hat{\Pi}}{dt}}_{<0},$$

where the first term captures the positive effect of tax on social environmental valuations (i.e., savings from environmental damages), and the second term is the negative effect of tax on industry profits. If $D'(\hat{Z})$ is small enough, then $A > 0$ and thus $t^* < t^{SO} = n\bar{\beta}D'(\hat{Z})$. The same intuition as earlier applies here. However, if $D'(\hat{Z})$ is large enough, then we may have a situation where the two effects are cancelled out or even the former effect dominates, i.e., $A \leq 0$. In this case, we would have $t^* \geq t^{SO} = n\bar{\beta}D'(\hat{Z})$. This is because the significant environmental damage caused by waste plays an increasing role in both lobby groups' welfare calculations. From the capitalists' perspective, the loss from environmental damages caused by waste can be severe enough to dominate any profit gains due to a lower tax. As a result, capitalists will diminish their lobbying efforts. Meanwhile, in response to the significant environmental damage, environmentalists will lobby more aggressively. Consequently, the political tax may overshoot the Pigouvian level.

# 4 The effects of green movement

In this section, we analyze how strengthening green lobbying – measured by an increase in the number of environmentalists and the joining members' associated environmental valuation – might impact the environmental tax and by extension firms' decision to export waste. This can be interpreted as an environmental movement in which increased environmental awareness has arguably enabled environmentalists to mobilize more ordinary people to join forces and exert pressure on governments to take more action.

Assume that the number of capitalists ($n_C$) and the total population ($n$) are fixed. As more workers ($n_W$) become environmentalists ($n_E$) and their associated environmental valuation $\beta_W$ also increases to $\beta_E$, it follows that

**Proposition 2.** *The effects of strengthening environmental lobbying on the tax can be characterized by*

$$\frac{dt^*}{dn_E} = \frac{\frac{1+\delta}{\delta+\lambda_0}\frac{1}{n_W}\left[n_W(\beta_E - \beta_W)D'(\hat{Z}) - \left(t^* - n\bar{\beta}D'(\hat{Z})\right)\right]}{\frac{d\Omega}{dt}}.$$

*If $t^* < n\bar{\beta}D'(\hat{Z})$, then*

$$\frac{dt^*}{dn_E} > 0, \quad \frac{d\hat{Q}}{dn_E} = \frac{d\hat{Q}}{dt}\frac{dt}{dn_E} > 0\,;$$

*and if $t^* > n\bar{\beta}D'(\hat{Z})$ and $n_W(\beta_E - \beta_W)D'(\hat{Z}) < \left(t^* - n\bar{\beta}D'(\hat{Z})\right)$, then*

$$\frac{dt^*}{dn_E} < 0, \quad \frac{d\hat{Q}}{dn_E} = \frac{d\hat{Q}}{dt}\frac{dt}{dn_E} < 0.$$

*Proof.* See Appendix C. □

Since $\frac{d\Omega}{dt} > 0$, the sign of $\frac{dt^*}{dn_E}$ is determined by the two terms in the square bracket: $n_W(\beta_E - \beta_W)D'(\hat{Z})$ and $\left(t^* - n\bar{\beta}D'(\hat{Z})\right)$. Note that $(\beta_E - \beta_W) > 0$ measures the increase in environmental valuation when one worker becomes an environmentalist. Therefore, the first term $n_W(\beta_E - \beta_W)D'(\hat{Z}) > 0$ captures the social marginal benefit of this environmental movement, whereas the second term $\left(t^* - n\bar{\beta}D'(\hat{Z})\right)$ reflects the political distortion of the pollution tax relative to the socially optimal level, thus representing the marginal social loss from lobbying. If the politically chosen tax is inefficiently weak, then an increase in the size of the green lobby will lead to a higher tax and more waste to be exported. However, if the pollution tax is inefficiently strict and the marginal benefit of the environmental movement is less than the marginal loss from lobbying, then an increase in the size of the green lobby results in a lower tax and less waste to be exported.

Starting with a situation where $t^* < n\bar{\beta}D'(\hat{Z}))$ when the capitalists have a dominant lobbying power (i.e., when $\beta_W \geq \bar{\beta}$, or $\beta_W < \bar{\beta}$ with $D'(\hat{Z})$ being small enough). In this case, $\frac{dt^*}{dn_E} > 0$, and by extension, $\frac{d\hat{Q}}{dn_E} = \frac{d\hat{Q}}{dt}\frac{dt}{dn_E} > 0$. This result is highly intuitive. As more people become environmentally concerned and join the environmental lobbying, while the number of capitalists is fixed, this translates into more power exercised by the environmental lobby group. As a result, the government will respond to this boosted political pressure by increasing environmental policy stringency. This ultimately pushes up the cost of disposing of waste domestically, thereby resulting in more waste being exported to other countries. This conclusion is similar to McAusland (2008), which demonstrates that when facing increased political pressure exercised by the organized interest groups, regulators have an incentive to increase regulation on pollution that is a by-product of consumption activities and thereby induce firms to export waste to lower environmental regulation locations. Eventually, when environmentalists are able to mobilize all the workers to join forces, the resulting equilibrium tax will equate to the social optimum.

However, when the environmentalists have a dominant lobbying power (i.e., when $\beta_W < \bar{\beta}$ with $D'(\hat{Z})$ being large enough), the political economy equilibrium tax is higher than the socially optimal level ($t^* - n\bar{\beta}D'(\hat{Z}) > 0$). Now both the terms $n_W(\beta_E - \beta_W)D'(\hat{Z}(t))$ and $t^* - n\bar{\beta}D'(\hat{Z})$ are positive. If the former exceeds the latter, then we still have $\frac{dt^*}{dn_E} > 0$, $\frac{d\hat{Q}}{dn_E} = \frac{d\hat{Q}}{dt}\frac{dt}{dn_E} > 0$. However, if the former is less than the latter, i.e., $n_W(\beta_E - \beta_W)D'(\hat{Z}) < \big(t^* - n\bar{\beta}D'(\hat{Z})\big)$, then we have

$$\frac{dt^*}{dn_E} < 0, \quad \frac{d\hat{Q}}{dn_E} = \frac{d\hat{Q}}{dt}\frac{dt}{dn_E} < 0.$$

This is quite surprising, as one would expect that a stronger environmental lobby (due to a larger size) should always lead to a higher tax. Although this result may seem counterintuitive, the main intuition behind it is that we are starting with a situation where the tax is already very high, which means that the marginal benefit of any additional effort to strengthen environmental policy would be very small, but the marginal loss associated with it could be significant. While environmentalists enjoy protecting the country from suffering too much waste-induced environmental damage, they also derive part of their income from the lump-sum tax revenues and thus the consumption of the numeraire good. When the additional benefits of lower environmental damage cannot exceed their loss of income, they would like to trade off the two and exchange part of the environmental protection for additional income, which lowers the tax. As the number of environmental lobbyists increases, the desire for the tradeoff also increases, which further reduces the tax. As the pollution tax decreases, the cost of disposing of waste domestically goes down, and thereby less waste will be exported to other countries. Eventually, when all workers become environmentalists, the equilibrium tax will equate to the socially optimum level. This result is similar to Aidt (1998), which demonstrates that the competitive political process and the fact that lobby groups adjust their economic objectives to reflect environmental concerns will lead to the political internalization of environmental externalities.

# 5 Direct political competition

Before we model the indirect political competition game, it is necessary to characterize the equilibrium political contributions of each organized lobby group. Let $t^C$ denote the equilibrium tax that maximizes the joint welfare of the government and the industrial lobby group. Then, $t^C$ must be the solution to the problem

$$\max_t \hat{G}_C(t) = \Big[J_C(t) - B_C + \delta J(t)\Big],$$

or equivalently

$$\max_t \hat{G}_C(t) = J_C(t) + \delta J(t). \tag{8}$$

Similarly, let $t^E$ denote the equilibrium tax that maximizes the joint welfare of the government and the environmental lobby group, i.e., $t^E$ is the solution to the problem

$$\max_t \hat{G}_E(t) = \Big[J_E(t) - B_E\Big] + \delta J(t),$$

or equivalently

$$\max_t \hat{G}_E(t) = J_E(t) + \delta J(t). \tag{9}$$

**Lemma 2.** *The equilibrium tax $t^C$ is implicitly defined as the solution to*

$$\Omega_C(t) \equiv \Big(t - n\bar{\beta}D'(\hat{Z})\Big) + \frac{\lambda_C}{\lambda_C + \delta}\Big[(n\bar{\beta} - n\beta_C)D'(\hat{Z}) + \frac{1-\lambda_C}{\lambda_C}\frac{d\hat{\Pi}}{d\hat{Z}}\Big] = 0, \tag{C2}$$

*while the equilibrium tax $t^E$ is implicitly defined as the solution to*

$$\Omega_E(t) \equiv \Big(t - n\bar{\beta}D'(\hat{Z})\Big) - \frac{\lambda_E}{\lambda_E + \delta}\Big[(n\beta_E - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}\Big] = 0, \tag{C3}$$

*where $\lambda_C = \frac{n_C}{n}$ and $\lambda_E = \frac{n_E}{n}$ denote the fractions of the population that belong to the organized industrial and environmental lobby group, respectively.*

*Proof.* See Appendix D. □

Since $\beta_E \geq \bar{\beta} \geq \beta_C$ and $\frac{d\hat{\Pi}}{d\hat{Z}} = \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt} > 0$, we must have

$$t^C < t^{SO} = n\bar{\beta}D'(\hat{Z}) < t^E.$$

That is, the equilibrium tax will pivot in favour of the lobby group when the other one is absent or unorganized. Further, we can establish the following result:

**Proposition 3.** *The equilibrium political contributions for the industrial and environmental lobby group are given by*

$$\psi_C(t^*, t^E) = \Big[J_E(t^E) + \delta J(t^E)\Big] - \Big[J_E(t^*) + \delta J(t^*)\Big], \tag{10}$$

*and*

$$\psi_E(t^*, t^C) = \Big[J_C(t^C) + \delta J(t^C)\Big] - \Big[J_C(t^*) + \delta J(t^*)\Big], \tag{11}$$

*respectively, where $t^C$ and $t^E$ are implicitly defined as the solution to (C2) and (C3).*

Proposition 3 demonstrates that lobbies will contribute up to the point where the change in the economic policy is exactly compensated by the marginal cost of contribution. Take the equilibrium contribution of the environmental lobby group as an example. This group takes the political contribution of the other group as given and knows that, if it does not enter into the political game, the government will choose the tax $t^C$ that maximizes the sum of aggregate social welfare and the industrial lobby group's net benefits. Therefore, if the environmental lobbies intend to affect the policy outcome with environmental tax given by $t^*$, it must offer a contribution that gives the government at least what it could achieve by ignoring their preferences. That is, one must have $\psi_E(t^*) + \psi_C(t^*) + \delta J(t^*) \geq \psi_C(t^C) + \delta J(t^C)$. The green lobby group does not contribute more than necessary to induce the equilibrium environmental tax $t^*$. Consequently, the equilibrium contribution of the green lobbies is exactly equal to the difference between what the government and the industrial lobby group could jointly achieve when the green lobbies' interest is ignored ($\psi_C(t^C) + \delta J(t^C)$) and when it is considered ($\psi_C(t^*) + \delta J(t^*)$). The same reasoning applies to the political contribution of the industrial lobby group.

# 6 Indirect political competition

In the previous section, we have focused on the direct political contribution mechanisms of environmental lobbying on the waste trade. However, as demonstrated in Yu (2005), political contributions from environmental lobby groups are typically much smaller compared to those from industrial ones. The success of green lobbying can thus be largely attributed to its greater effectiveness in public persuasion and the growing public environmental awareness. Furthermore, as identified by Connelly et al. (2012), ENGOs can engage in various activities such as producing scientific research and reports, organizing protests, staging public stunts and more to influence policymakers' perceived political support. Additionally, ENGOs often use environmental litigation and courts to achieve their goals (Bentata and Faure, 2015). All these strategies aim to influence public perception of waste-induced environmental issues.

In this section, we follow Yu (2005) and model a policy game at the first stage where lobbies engage in indirect political competition by sending messages to workers to influence their subjective beliefs regarding waste-induced environmental damages. We first characterize the political equilibrium outcome, and then analyze how an increase in the general public's initial environmental awareness and waste absorption fee could indirectly and directly affect trade in waste. The former can be seen as a measure of strengthening green lobbying, as one main objectives of the public campaigns launched by environmental lobby groups is to increase general public awareness about environmental damage. The latter can be viewed as a response by the South to increase domestic environmental regulation or impose some forms of trade restrictions to avoid the country becoming a waste haven.

## 6.1 Public persuasion

We now move to model the first-stage indirect lobbying game. Let $m_E$ and $m_C$ denote the number of messages sent by environmental and industrial lobby groups, respectively, and denote by $\beta_0$ the prior belief of workers about the scale of waste-induced environmental damage. Workers then update their beliefs based on the messages they receive from the lobbies and thus the posterior belief of workers' valuation for environmental quality $\beta_W$ can be expressed as a function of $m_E$ and $m_C$:

$$\beta_W = \Gamma(m_E, m_C).$$

We make the following assumptions:

(i) $\forall (m_E, m_C) \in \mathcal{R}^2_+$,

$$\Gamma_E = \frac{\partial \Gamma(m_E, m_C)}{\partial m_E} > 0, \quad \Gamma_C = \frac{\partial \Gamma(m_E, m_C)}{\partial m_C} < 0,$$

i.e., workers' belief in the scale of environmental damage is increasing (respectively decreasing) in the number of messages sent by the environmental (respectively industrial) lobby group;

(ii) $\forall (m_E, m_C) \in \mathcal{R}^2_+$,

$$\Gamma_{EE} = \frac{\partial^2 \Gamma(m_E, m_C)}{\partial m_E^2} \leq 0, \quad \Gamma_{CC} = \frac{\partial^2 \Gamma(m_E, m_C)}{\partial m_C^2} \geq 0,$$

$$\Gamma_{EC} = \frac{\partial^2 \Gamma(m_E, m_C)}{\partial m_E \partial m_C} = \Gamma_{CE} = \frac{\partial^2 \Gamma(m_E, m_C)}{\partial m_C \partial m_E} \gtreqless 0,$$

i.e., there are decreasing returns to scale for sending messages and the messages sent by the two lobby groups can be complements, substitutes or independent.

(iii) If $m_E = m_C$,

$$\Gamma(m_E, m_C) = \beta_0 > 0,$$

i.e., workers' posterior and prior beliefs are the same when the two lobbies send the same number of messages.

By setting the partial cross-derivative equal to 0, Yu (2005) assumes that no interactions exist between the messages sent by environmental and industrial lobby groups. However, there is no strong rationale to believe that messages from one lobby group would not affect the effectiveness of the opposing group's messages in shaping the public's perception of environmental damage. As argued in Cheikbossian and Hafidi (2022), the interplay between competing messages is highly likely to influence public beliefs. For instance, if the number of messages sent by one lobby group is sufficiently large, it could dominate the messages sent by the other group. Meanwhile, if the message is excessive, it could be counter-productive and backfire. The excessive green self-promotion by producers is one such example when getting spotted by consumers and activists (Lyon and Montgomery, 2013).

Let the cost of sending messages be $c_j(m_j)$, with $c'(m_j) > 0$, $c''(m_j) \geq 0$ and $c(0) = 0$ for $j = E, C$. The environmental lobby group chooses $m_E$ to maximize

$$\mathcal{L}_E(m_C, m_E) = J_E(t^*) - \psi_E(t^*, t^C) - c_E(m_E),$$

while the industrial lobby group chooses $m_C$ to maximize

$$\mathcal{L}_C(m_C, m_E) = J_C(t^*) - \psi_C(t^*, t^E) - c_C(m_C).$$

Using Proposition 3 to replace the political contributions, the objective functions of the lobby groups become

$$\max_{m_E} \mathcal{L}_E(m_C, m_E) = J_E(t^*) + J_C(t^*) + \delta J(t^*) - \left[J_C(t^C) + \delta J(t^C)\right] - c_E(m_E),$$
$$\max_{m_C} \mathcal{L}_C(m_C, m_E) = J_C(t^*) + J_E(t^*) + \delta J(t^*) - \left[J_E(t^E) + \delta J(t^E)\right] - c_C(m_C).$$

Using the envelope theorem, the first-order conditions with respect to messages yield

$$\frac{\partial \mathcal{L}_E(m_C, m_E)}{\partial m_E} = \Gamma_E(m_C, m_E)\delta n_W \Big( D(\hat{Z}(t^C)) - D(\hat{Z}(t^*)) \Big) - c_E'(m_E) = 0, \qquad (12)$$

$$\frac{\partial \mathcal{L}_C(m_C, m_E)}{\partial m_C} = \Gamma_C(m_C, m_E)\delta n_W \Big( D(\hat{Z}(t^E)) - D(\hat{Z}(t^*)) \Big) - c_C'(m_C) = 0. \qquad (13)$$

The system of equations (12) and (13) admits a pair of interior solutions for the equilibrium number of messages $(m_E^*, m_C^*)$, provided that the respective second-order conditions are negative.

It would be ideal to explicitly derive the equilibrium levels of messages, political contributions and environmental policy as a function of parameters of the model, but as shown earlier, there are only implicit solutions. To gain further insights into how strengthening environmental lobbying and increasing foreign policy stringency could affect trade in waste both indirectly and directly, we propose some simple functional forms in the following subsection for illustration.

## 6.2 Strategic interaction in messages

Suppose the production function, utility function, damage function, cost function, and worker's posterior environmental valuation function take the following forms, respectively:

$$Y = F(K, L) = 2K^{\frac{1}{2}} L^{\frac{1}{2}}, \quad u(y) = Ay - \frac{1}{2}y^2, \quad D(Z) = Z,$$

$$\eta(Q) = \frac{1}{2}Q^2, \quad c(m_j) = \frac{1}{2}m_j^2, \ \forall j \in E, C,$$

$$\beta_W = \Gamma(m_E, m_C) = \beta_0 + m_E - m_C, \tag{14}$$

which will allow us to obtain an analytical solution. Note that we now assume, like Yu (2005), that the messages sent by the two pressure groups have independent effects on the general public's perception of environmental damage (that is, $\Gamma_{EC} = \Gamma_{CE} = 0$). We are well aware of the limitations of this hypothesis, but given the richness of our basic analytical framework, it is essential for obtaining explicit analytical solutions. Without loss of generality, we normalize $n = 1$, and thus $\lambda_C = n_C$, $\lambda_E = n_E$ and $\lambda_W = n_W$. For simplicity, let $\bar{K} = 1$, $\beta_E = 1$, $\beta_C = 0$. Given these functional forms, we assume:

**Assumption 1.** *The set of parameter values of the model must satisfy:*

$$0 < \mu < p = 1 < A, \tag{A1}$$

$$\delta - 1 + 2n_C > 0, \tag{A2}$$

$$(\delta + 2n_E)(\delta - 1 + 2n_C + 2n_E) + 3(\delta n_W)^2(2n_C - 1) > 0. \tag{A3}$$

Assumption (A1) states that if the exogenous world price of the manufactured good is normalized to 1 (implying that the market size $A$ is greater than 1), then $\mu < 1$ guarantees that the optimal consumption and production of the manufactured good, exported waste and pollution are strictly positive. (A2) and (A3) ensure the existence of the optimal political taxes and number of messages. Under (A1)-(A3), the best response functions of messages are given by

$$m_E(m_C) = \frac{\delta n_W \Big[ 3n_E\big(\delta(1-2n_E) - 1 + 2n_C\big) + (2+\mu)(1+\delta)n_E - 6n_E\delta n_W(\beta_0 - m_C) \Big]}{(\delta - 1 + 2n_C)\,(\delta - 1 + 2n_C + 2n_E) + 6n_E(\delta n_W)^2}, \tag{15}$$

and

$$m_C(m_E) = \frac{\delta n_W \Big[ 3\big((1+\delta)n_E + \delta n_W(\beta_0 + m_E)\big)(2n_C - 1) + (2+\mu)(\delta + n_E - \delta n_C) \Big]}{(\delta + 2n_E)\,(\delta - 1 + 2n_C + 2n_E) + 3(\delta n_W)^2(2n_C - 1)}, \tag{16}$$

We can first establish the following result:

**Lemma 3.** *Suppose (A1)-(A3) hold. If* $\frac{1}{2} - \frac{1}{2}\frac{(\delta+2n_E)^2}{(\delta+2n_E)+3(\delta n_W)^2} < n_C < \frac{1}{2}$, *then*

$$\frac{dm_E(m_C)}{dm_C} > 0, \quad \frac{dm_C(m_E)}{dm_E} < 0.$$

*However, if* $n_C > \frac{1}{2}$, *then*

$$\frac{dm_E(m_C)}{dm_C} > 0, \quad \frac{dm_C(m_E)}{dm_E} > 0.$$

*Proof.* See Appendix E. □

Lemma 3 shows that the nature of strategic interactions between policy actors crucially depends on the size of the lobby groups. If the fraction of the population that belongs to the industrial lobby group is less than $\frac{1}{2}$, then the best response function of the environmental lobby group in the indirect lobbying game is upward sloping while that of the industrial lobby group is downward sloping. In this case, the messages sent by the two lobby groups are strategic substitutes. However, if the number of capitalists in the population is very large (i.e., $n_C > \frac{1}{2}$), then both the best response functions in the indirect lobbying game are upward sloping, indicating that the messages sent by the two lobby groups are strategic complements.

Using (15) and (16), we can solve the equilibrium number of messages $(m_E^*, m_C^*)$, which further allows us to derive the equilibrium posterior environmental valuation of the general public, the political taxes and contributions. More specifically,

**Proposition 4.** *Suppose (A1)-(A3) hold, and that the set of parameter values of the model also satisfies (A4), given by*

$$\chi^* > 0, \quad \phi^* > 0, \tag{A4}$$

*where $\chi^*$ and $\phi^*$ are given below. Then, there exists a unique interior solution for the pair of equilibrium number of messages $(m_E^*, m_C^*)$ defined by*

$$m_E^* = \frac{\chi^*}{\xi^*}, \quad m_C^* = \frac{\phi^*}{\xi^*}, \tag{17}$$

*where*

$$\begin{aligned}
\xi^* &= \Big[(\delta - 1 + 2n_C)(\delta + 2n_E)\,(\delta - 1 + 2n_C + 2n_E)\Big] + 3(\delta n_W)^2\Big[2n_E(2n_E + \delta) + (2n_C - 1)(\delta - 1 + 2n_C)\Big],\\
\chi^* &= \Big[\delta n_W n_E\Big(3(\delta n_W)^2 + (1+\delta)(\delta + 2n_E)\Big)\Big](2+\mu) - \Big[6(\delta n_W)^2 n_E(\delta + 2n_E)\Big]\beta_0\\
&\quad + \Big[3\delta n_W\Big(3(\delta n_W)^2(2n_C - 1) - (\delta + 2n_E)(1 - 2n_C + \delta(2n_E - 1))\Big)\Big]n_E,\\
\phi^* &= \Big[\delta n_W\Big(\delta(1 - n_C)(\delta - 1 + 2n_C) + n_E(\delta - 1 + 2n_C + 3(\delta n_W)^2)\Big)\Big](2+\mu)\\
&\quad + \Big[3(\delta n_W)^2\,(2n_C - 1)\,(\delta - 1 + 2n_C)\Big]\beta_0 + \Big[3\delta n_W\,(2n_C - 1)\Big(2n_C - 1 + \delta\,(2n_C + \delta + 3\delta n_W^2)\Big)\Big]n_E.
\end{aligned}$$

*The equilibrium posterior valuation of the environmental damage by workers is given by*

$$\beta_W^* = \beta_0 + m_E^* - m_C^*,$$

*and the equilibrium taxes are*

$$t_{eq}^* = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W^*\big) - (1 - n_C - n_E)(2+\mu)}{3\,(\delta - 1 + 2n_C + 2n_E)},$$

$$t_{eq}^{C} = \frac{3\big(\delta n_E + \delta n_W \beta_W^*\big) - (1-n_C)\,(2+\mu)}{3(\delta - 1 + 2n_C)},$$
$$t_{eq}^{E} = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W^*\big) + n_E(2+\mu)}{3(\delta + 2n_E)},$$

*with the equilibrium political contributions to the environmental and industrial lobby groups defined by*

$$\psi_E^*(t_{eq}^*, t_{eq}^C) = \Big[J_C(t_{eq}^C) + \delta J(t_{eq}^C)\Big] - \Big[J_C(t_{eq}^*) + \delta J(t_{eq}^*)\Big],$$
$$\psi_C^*(t_{eq}^*, t_{eq}^E) = \Big[J_E(t_{eq}^E) + \delta J(t_{eq}^E)\Big] - \Big[J_E(t_{eq}^*) + \delta J(t_{eq}^*)\Big].$$

*Proof.* See Appendix E. □

## 6.3 Comparative statistics

As shown in Proposition 4, the political equilibrium outcome depends on many parameters of the model: $n_C, n_E, n_W, \delta, \mu, \beta_0$. To obtain further insights into how a change in the initial environmental awareness $\beta_0$ and the waste absorption fee $\mu$ might affect the political equilibrium, we consider a specific group size distribution. That is, we consider a polar case where the industrial lobby group size is approximated to be negligible in the population, i.e., $n_C = 0$, while the size of the green lobby is as large as that of the general population, i.e., $n_E = n_W = \frac{1}{2}$. This case is not prohibitively restrictive, as it is reasonable to assume that the firms are owned by a very few capitalists. Meanwhile, a considerable portion of the population is becoming more environmentally conscious, and they are active green lobbyists.

With $n_C = 0$ and $n_E = n_W = \frac{1}{2}$, the equilibrium number of messages becomes

$$m_E^* = \frac{\delta^2(5 - 12\beta_0 + 7\mu) + 4\delta(1 - 3\beta_0 + 2\mu) - 4(1-\mu)}{8(2+\delta)(2\delta - 1)},$$
$$m_C^* = \frac{\delta^2(1 - 12\beta_0 + 11\mu) + 4\delta(-2 + 3\beta_0 - \mu) + 4(1-\mu)}{8(2+\delta)(2\delta - 1)},$$

and the equilibrium posterior environmental valuation, as well as the equilibrium political contributions, are given by

$$\beta_W^* = \beta_0 + m_E^* - m_C^*, \quad \psi_E^* = \frac{2(\delta-1)(m_E^*)^2}{3\delta^2}, \quad \psi_C^* = \frac{(\delta+1)(m_C^*)^2}{3\delta^2},$$

with the equilibrium political tax and waste exports defined by

$$t_{eq}^* = \frac{\beta_0 + m_E^* - m_C^*}{2} + \frac{3\delta - \mu + 1}{6\delta}, \quad Q^* = \frac{\beta_0 + m_E^* - m_C^*}{2} + \frac{3\delta(1-2\mu) - \mu + 1}{6\delta}.$$

We first characterize how strengthening environmental lobbying – measured by an increase in $\beta_0$ – could affect the equilibrium messages, political contributions, policy stringency and waste trade.

**Proposition 5.** *Suppose $n_C = 0$ and $n_E = n_W = \frac{1}{2}$. An increase in the initial environmental awareness $\beta_0$: (i) decreases both $m_E^*$ and $m_C^*$, but increases $\beta_W^*$; (ii) decreases both $\psi_E^*$ and $\psi_C^*$; (iii) increases both $t_{eq}^*$ and $Q^*$.*

*Proof.* See Appendix F. □

An increase in the initial public environmental awareness reduces the number of messages sent by both the green and industrial lobby groups. As $\beta_0$ increases, the marginal impact on the posterior environmental awareness $\beta_W^*$ due to additional messages sent by either group is lower (because of the additive specification of $\beta_W$), while the cost of sending messages is not affected by $\beta_0$. As a result, both the lobbies send fewer messages. In other words, if the public is already very sensitive to environmental damage, there is less room for lobbies to shape their perception of damage, leading them to be less active in indirect lobbying.

In addition, the overall effect of an increase in $\beta_0$ on the post-environmental public awareness equilibrium is always positive, leading to an increase in $\beta_W^*$. This helps the environmental pressure group by improving its negotiating position with the government and thus also reduces its direct political contributions. Capitalists thus face less opposition from the green lobby in the game of influence with the government. While an increase in the tax always decreases the profit, it does so at a decreasing rate because of the tax refund for every unit of waste that is being exported. For these two reasons, the industrial lobby group can afford to be less aggressive in direct competition, making fewer direct political contributions as well. Consequently, as $\beta_0$ increases, the equilibrium political tax rises, ultimately leading to more waste being exported.

It is worth noting that the results of Proposition 5 sharply contrast with those of Yu (2005) insofar as the two channels of policy influence are complementary to each other with a change in the general population's initial environmental awareness. Both lobbies are less active in direct and indirect lobbying, while in Yu (2005), both lobbies are more aggressive in one dimension (but not the same for both lobbies) and less aggressive in the other.

Next, we evaluate how an increase in the waste absorption fee $\mu$ could affect the equilibrium outcome. We obtain the following result:

**Proposition 6.** *Suppose $n_C = 0$ and $n_E = n_W = \frac{1}{2}$. An increase in the waste absorption fee $\mu$: (i) increases both $m_E^*$ and $m_C^*$, and increases (respectively decreases) $\beta_W^*$ for $1 < \delta \leq \bar{\delta} \equiv \frac{3+\sqrt{17}}{2}$ (respectively $\delta > \bar{\delta}$); (ii) increases both $\psi_E^*$ and $\psi_C^*$; (iii) decreases $Q^*$ and increases (decreases) $t_{eq}^*$ when $\delta \in (1, 2]$ (when $\delta > 2$).*

*Proof.* See Appendix F. □

The effect of an increase in the waste absorption fee intensifies the competition between lobbies in both the indirect and direct lobbying games. These results are quite intuitive, since a higher waste absorption fee makes the domestic environmental policy more decisive both for producers' profits and for the environmental damage to which the green lobby is more sensitive than the rest of the population. So, as in the case of an increase in the general population's initial environmental awareness, the two channels that lobbies can use to influence environmental policy are complementary to each other, except that an increase in the waste absorption fee induces lobbies to be more aggressive, not less, in their two means of influence. One can also observe that the equilibrium posterior belief $\beta_W^*$ of the environmental damage is increased with a higher waste absorption fee, except when the government puts a large weight on total welfare (i.e. $\delta > \bar{\delta} \approx 3.56$). In other words, the green lobby group reacts more strongly through indirect lobbying to an increase in the tax on waste disposal when direct political contributions are not too small relative to the general welfare in the objective function of the government; otherwise, it is the producer lobby that reacts more strongly in indirect lobbying, which leads $\beta_W^*$ to decrease.

Naturally, a higher waste absorption fee in the South decreases waste exports from the North. It can also decrease the equilibrium environmental tax, provided that the government gives sufficient weight to total welfare relative to the political contributions in its objective function (i.e. $\delta > 2$). However, if the government values political contributions and total welfare in a more balanced way (i.e. $\delta \in (1, 2]$), the equilibrium tax increases. The explanation is as follows. The general welfare includes the producer's profits, the labour income (constant), the consumer surplus of all agents – whether members are of an organized lobby group or not – and tax revenues equally redistributed among all agents, minus the total environmental damage. The consumer surplus of the manufactured good is constant (due to the exogenous world price imposed on this small open economy), but tax revenues on the production of this good are endogenous, which depends on the quantity produced, and so is the consumption of the numeraire good. A higher waste absorption fee discourages the production of the manufactured good, thus reducing environmental damage. If the government strongly values total welfare, it must also ensure sufficient tax revenues, thereby maintaining the quantity of manufactured goods produced domestically. This consideration will prompt the government to offset higher foreign waste-treatment costs by reducing the tax on domestic production.

# 7 Conclusion

In this paper, we propose a micro-founded model to investigate the effects of environmental lobbying on international trade in waste. We first develop a direct lobbying framework à la Grossman and Helpman (1994) that emphasizes the potential impact of green lobbies on the environmental policy and how North-to-South waste flows are affected through this policy channel. We show that the politically chosen policies are ambiguous relative to the socially optimal levels, depending on the heterogeneity of environmental preferences and the degree of pollution damages from waste. This in turn leads to ambiguous effects of environmental lobbying on the North-to-South waste trade. Further, we build an indirect lobbying model based on Yu (2005) to analyze the impact of indirect lobbying through public persuasion by interest groups on environmental policy stringency, political contributions and waste exports. We show that a stronger initial environmental awareness of the general public induces a complementarity between direct and indirect competition, causing both the environmental and industrial lobby groups to behave less aggressively in their two means of influence. This results in a more stringent environmental policy and more waste to be exported. Finally, we demonstrate that an increase in the foreign waste absorption fee intensifies the competition between lobbies in both the indirect and direct lobbying games, ultimately leading to lower volumes of waste exports.

# References


**Aidt, Toke S.** 1998. "Political internalization of economic externalities and environmental policy." *Journal of Public Economics*, 69(1): 1–16.

**Aidt, Toke S.** 2010. "Green taxes: Refunding rules and lobbying." *Journal of Environmental Economics and Management*, 60(1): 31–43.

**Baggs, Jen.** 2009. "International trade in hazardous waste." *Review of International Economics*, 17(1): 1–16.

**Bentata, Pierre, and Michael Faure.** 2015. "The role of Engos in environmental litigation: a French case study." *Environmental Policy and Governance*, 25(6): 459–473.

**Bernard, Sophie.** 2015. "North–south trade in reusable goods: Green design meets illegal shipments of waste." *Journal of Environmental Economics and Management*, 69: 22–35.

**Bernheim, B Douglas, and Michael D Whinston.** 1986. "Menu auctions, resource allocation, and economic influence." *The Quarterly Journal of Economics*, 101(1): 1–31.

**Binder, Seth, and Eric Neumayer.** 2005. "Environmental pressure group strength and air pollution: An empirical analysis." *Ecological Economics*, 55(4): 527–538.

**Cassing, James H, and Ngo Van Long.** 2021. "Trade in trash: A political economy approach." *European Journal of Political Economy*, 67: 101982.

**Cheikbossian, Guillaume, and Houda Hafidi.** 2022. "Lobbying, public persuasion, and environmental policy under imperfect competition." *Annals of Economics and Statistics*, , (145): 91–116.

**Conconi, Paola.** 2003. "Green lobbies and transboundary pollution in large open economies." *Journal of International Economics*, 59(2): 399–422.

**Connelly, James, Graham Smith, David Benson, and Clare Saunders.** 2012. *Politics and the environment: from theory to practice.* Routledge.

**Cosbey, Aaron, Susanne Droege, Carolyn Fischer, and Clayton Munnings.** 2020. "Developing guidance for implementing border carbon adjustments: lessons, cautions, and research needs from the literature." *Review of Environmental Economics and Policy*.

**Cropper, Maureen L, William N Evans, Stephen J Berardi, Maria M Ducla-Soares, and Paul R Portney.** 1992. "The determinants of pesticide regulation: A statistical analysis of EPA decision making." *Journal of Political Economy*, 100(1): 175–197.

**Dai, Miao.** 2023. *Environmental Lobbying on International Trade in Waste: Theory and Evidence.* CEE-M Working Papers hal-04198721, CEE-M, Universtiy of Montpellier, CNRS, INRA, Montpellier SupAgro.

**Fredriksson, Per G.** 1997. "The political economy of pollution taxes in a small open economy." *Journal of Environmental Economics and Management*, 33(1): 44–58.

**Fredriksson, Per G, Eric Neumayer, Richard Damania, and Scott Gates.** 2005. "Environmentalism, democracy, and pollution control." *Journal of Environmental Economics and Management*, 49(2): 343–365.

**Fünfgelt, Joachim, and Günther G Schulze.** 2016. "Endogenous environmental policy for small open economies with transboundary pollution." *Economic Modelling*, 57: 294–310.

**Gawande, Kishore, and Usree Bandyopadhyay.** 2000. "Is protection for sale? Evidence on the Grossman-Helpman theory of endogenous protection." *The Review of Economics and Statistics*, 82(1): 139–152.

**Goldberg, Pinelopi Koujianou, and Giovanni Maggi.** 1999. "Protection for sale: An empirical investigation." *American Economic Review*, 89(5): 1135–1155.

**Grossman, Gene M, and Elhanan Helpman.** 1994. "Protection for sale." *American Economic Review*, 84(4): 833.

**Grossman, Gene M., and Elhanan Helpman.** 2020. *Interest Groups and Trade Policy.* Princeton University Press.

**Guo, Liang, WD Walls, and Xiaoli Zheng.** 2023. "Waste Import Bans and Environmental Quality: Evidence from China's Electronic Waste Disposal Towns." *Environmental and Resource Economics*, 1–44.

**Higashida, Keisaku, and Shunsuke Managi.** 2014. "Determinants of trade in recyclable wastes: evidence from commodity-based trade of waste and scrap." *Environment and Development Economics*, 19(2): 250–270.

**Kalt, Joseph P, and Mark A Zupan.** 1984. "Capture and ideology in the economic theory of politics." *American Economic Review*, 74(3): 279–300.

**Keen, Michael, and Christos Kotsogiannis.** 2014. "Coordinating climate and trade policies: Pareto efficiency and the role of border tax adjustments." *Journal of International Economics*, 94(1): 119–128.

**Kellenberg, Derek.** 2012. "Trading wastes." *Journal of Environmental Economics and Management*, 64(1): 68–87.

**Kellenberg, Derek, and Arik Levinson.** 2014. "Waste of effort? International environmental agreements." *Journal of the Association of Environmental and Resource Economists*, 1(1/2): 135–169.

**Longhofer, Wesley, and Evan Schofer.** 2010. "National and global origins of environmental association." *American Sociological Review*, 75(4): 505–533.

**Lyon, Thomas P, and A Wren Montgomery.** 2013. "Tweetjacked: The impact of social media on corporate greenwash." *Journal of business ethics*, 118: 747–757.

**McAusland, Carol.** 2008. "Trade, politics, and the environment: Tailpipe vs. smokestack." *Journal of Environmental Economics and Management*, 55(1): 52–71.

**Olson, Mancur.** 1965. "The logic of collective action: Public goods and the theory of groups." *Cambridge, MA: Harvard University Press*.

**Pacca, Lucia, Daniele Curzi, Gordon Rausser, and Alessandro Olper.** 2021. "The Role of Party Affiliation, Lobbying, and Electoral Incentives in Decentralized US State Support of the Environment." *Journal of the Association of Environmental and Resource Economists*, 8(3): 617–653.

**Riddel, Mary.** 2003. "Candidate eco-labeling and senate campaign contributions." *Journal of Environmental Economics and Management*, 45(2): 177–194.

**Schleich, Joachim.** 1999. "Environmental quality with endogenous domestic and trade policies." *European Journal of Political Economy*, 15(1): 53–71.

**Shi, Xinzheng, and Ming-ang Zhang.** 2023. "Waste import and air pollution: Evidence from China's waste import ban." *Journal of Environmental Economics and Management*, 120: 102837.

**Sommer, Konstantin.** 2024. "The Chinese waste import ban and the emergence of waste havens within Europe." Tinbergen Institute Discussion Paper.

**Sterner, Thomas, and Lena Höglund Isaksson.** 2006. "Refunded emission payments theory, distribution of costs, and Swedish experience of NOx abatement." *Ecological Economics*, 57(1): 93–106.

**Wapner, Paul.** 1995. "Politics beyond the state environmental activism and world civic politics." *World Politics*, 47(3): 311–340.

**Yu, Zhihao.** 2005. "Environmental protection: A theory of direct and indirect competition for political influence." *The Review of Economic Studies*, 72(1): 269–286.

**Zhang, Zhi Min, Chengzheng Yu, and Jingting Li.** 2025. "Waste Import Ban and Water Pollution: Evidence from Rivers in Guangdong Province, China." *Resources, Conservation & Recycling Advances*, 200277.

# Appendices

## A Proof of Lemma 1

*Proof.* The equilibrium demand for labour in the manufacturing sector, $\hat{L}$, is implicitly given by equation (2): $(p-t)F_L(\bar{K}, L) = 1$. It follows that

$$\frac{d\hat{L}}{dt} = \frac{F_L}{(p-t)F_{LL}} < 0, \quad \frac{d\hat{Y}}{dt} = F_L\frac{d\hat{L}}{dt} = \frac{F_L^2}{(p-t)F_{LL}} < 0.$$

The equilibrium waste exports, $\hat{Q}$, can be implicitly obtained from equation (1): $t - \mu = \eta'(Q)$ as a function of $t$. Totally differentiate (1) with respect to $\hat{Q}$ and $t$ yields

$$\frac{d\hat{Q}}{dt} = \frac{1}{\eta''(Q)} > 0.$$

Therefore, the equilibrium pollution level is $\hat{Z}(t) = \hat{Y}(t) - \hat{Q}(t)$ with

$$\frac{d\hat{Z}}{dt} = \frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt} < 0.$$

Finally, using the envelope theorem, we can get

$$\frac{d\hat{\Pi}}{dt} = -\hat{Y} + \hat{Q} = -\hat{Z} < 0. \tag{18}$$

Notice that

$$\begin{aligned}
\frac{dJ_C}{dt} &= \frac{d\hat{\Pi}}{dt} + \frac{n_C}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - n_C\beta_C D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) \\
&= -\hat{Y} + \hat{Q} + \frac{n_C}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - n_C\beta_C D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right), \\
\frac{dJ_E}{dt} &= \frac{n_E}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - n_E\beta_E D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right), \\
\frac{dJ_W}{dt} &= \frac{n_W}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - n_W\beta_W D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right),
\end{aligned}$$

and thus

$$\frac{dJ}{dt} = t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) - n\bar{\beta}D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) = \left(t - n\bar{\beta}D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right).$$

Setting $\frac{dJ}{dt} = 0$ yields the socially optimal or Pigouvian tax: $t^{SO} = n\bar{\beta}D'(\hat{Z})$. □

# B Proof of Proposition 1

*Proof.* The first-order condition of (7) with respect to $t$ yields

$$\frac{d\hat{G}(t)}{dt} = \frac{dJ_C}{dt} + \frac{dJ_E}{dt} + \delta\frac{dJ}{dt} = 0.$$

That is,

$$-\hat{Y} + \hat{Q} + \frac{n_C + n_E}{n}\left[\hat{Y} - \hat{Q} + t\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)\right] - (n_C\beta_C + n_E\beta_E)D'(\hat{Z})\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right)$$

$$+\delta\left(t - n\bar{\beta}D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt} - \frac{d\hat{Q}}{dt}\right) = 0.$$

This equation reduces to

$$-\frac{n_W}{n}\hat{Z} + \left(\frac{n_C + n_E}{n}t - (n_C\beta_C + n_E\beta_E)D'(\hat{Z})\right)\frac{d\hat{Z}}{dt} + \delta\left(t - n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt} = 0.$$

Substitute with equation (18): $\frac{d\hat{\Pi}}{dt} = -\hat{Z}$ and use the result

$$n_C\beta_C + n_E\beta_E = n\bar{\beta} - n_W\beta_W = \frac{n_C + n_E + n_W}{n}n\bar{\beta} - n_W\beta_W = \frac{n_C + n_E}{n}n\bar{\beta} - \frac{n_W}{n}(n\beta_W - n\bar{\beta}),$$

the equation becomes

$$\frac{n_W}{n}\frac{d\hat{\Pi}}{dt} + \left[\frac{n_C + n_E}{n}t - \left(\frac{n_C + n_E}{n}n\bar{\beta} - \frac{n_W}{n}(n\beta_W - n\bar{\beta})\right)D'(\hat{Z})\right]\frac{d\hat{Z}}{dt} + \delta\left(t - n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt} = 0.$$

Define $\frac{n_C}{n} = \lambda_C$ and $\frac{n_E}{n} = \lambda_E$ and let $\lambda_0 = \lambda_C + \lambda_E$. Then,

$$(1-\lambda_0)\frac{d\hat{\Pi}}{dt} + \left[\lambda_0\left(t - n\bar{\beta}D'(\hat{Z})\right) + (1-\lambda_0)(n\beta_W - n\bar{\beta})D'(\hat{Z})\right]\frac{d\hat{Z}}{dt} + \delta\left(t - n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt} = 0.$$

Combine terms, we have

$$\frac{d\hat{G}(t)}{dt} = (\lambda_0 + \delta)\left(t - n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt} + (1-\lambda_0)\left[(n\beta_W - n\bar{\beta})D'(\hat{Z})\frac{d\hat{Z}}{dt} + \frac{d\hat{\Pi}}{dt}\right] = 0.$$

Thus, when both environmentalists and capitalists are organized, the political economy equilibrium tax $t^*$ is characterized by the following equation:

$$\frac{\frac{d\hat{G}(t)}{dt}}{(\lambda_0 + \delta)\frac{d\hat{Z}}{dt}} = \Omega \equiv \left(t - n\bar{\beta}D'(\hat{Z}(t))\right) + \frac{1-\lambda_0}{\delta + \lambda_0}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t)) + \frac{d\hat{\Pi}}{d\hat{Z}}\right] = 0, \tag{19}$$

where

$$\lambda_0 = \frac{n_C + n_E}{n} = \lambda_C + \lambda_E, \quad \frac{d\hat{\Pi}}{d\hat{Z}} = \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt} > 0.$$

Note that for $t^*$ to be a maximum, we need to ensure that the second-order condition of the government's maximization with respect to $t$ is negative, i.e.,

$$\frac{d^2\hat{G}(t)}{dt^2} = (\lambda_0+\delta)\frac{d^2\hat{Z}}{dt^2}\Omega + (\lambda_0+\delta)\frac{d\hat{Z}}{dt}\frac{d\Omega}{dt} < 0.$$

Since $\Omega = 0$ and $\frac{d\hat{Z}}{dt} < 0$, we must have

$$\frac{d\Omega}{dt} = 1 - n\bar{\beta}D''(\hat{Z})\frac{d\hat{Z}}{dt} + \frac{1-\lambda_0}{\delta+\lambda_0}\left((n\beta_W - n\bar{\beta})D''(\hat{Z})\frac{d\hat{Z}}{dt} + \frac{\frac{d^2\hat{\Pi}}{dt^2}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right) > 0.$$

□

# C Proof of Proposition 2

*Proof.* Given $n = n_C + n_E + n_W$, we must have

$$\frac{dn_C}{dn_E} = \frac{dn}{dn_E} = 0, \quad \frac{dn_W}{dn_E} = -1, \quad \frac{d\lambda_0}{dn_E} = \frac{1}{n},$$

$$\frac{d\frac{1-\lambda_0}{\delta+\lambda_0}}{dn_E} = \frac{-\frac{1}{n}(\delta+\lambda_0) - \frac{1}{n}(1-\lambda_0)}{(\delta+\lambda_0)^2} = \frac{-\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2} < 0,$$

$$\frac{d\beta_C}{dn_E} = \frac{d\beta_W}{dn_E} = \frac{d\beta_E}{dn_E} = 0, \quad \frac{dn\bar{\beta}}{dn_E} = \frac{d(n_C\beta_C + n_E\beta_E + n_W\beta_W)}{dn_E} = \beta_E - \beta_M > 0.$$

Rewrite equation (C1) as

$$t^* = n\bar{\beta}D'(\hat{Z}(t^*)) - \frac{1-\lambda_0}{\delta+\lambda_0}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t^*)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right],$$

then

$$\frac{dt^*}{dn_E} = (\beta_E-\beta_W)D'(\hat{Z}(t^*)) + n\bar{\beta}D''(\hat{Z}(t^*))\frac{d\hat{Z}}{dt}\frac{dt}{dn_E} + \frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t^*)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right]$$

$$-\frac{1-\lambda_0}{\delta+\lambda_0}\left[-(\beta_E-\beta_W)D'(\hat{Z}(t^*)) + (n\beta_W - n\bar{\beta})D''(\hat{Z}(t^*))\frac{d\hat{Z}}{dt}\frac{dt}{dn_E} + \frac{\frac{d^2\hat{\Pi}}{dt}\frac{dt}{dn_E}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{dt}{dn_E}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right].$$

Combining terms on the right-hand side, we have

$$\frac{dt^*}{dn_E} = \frac{1+\delta}{\delta+\lambda_0}(\beta_E-\beta_W)D'(\hat{Z}(t^*)) + \frac{(1+\delta)n\bar{\beta} - (1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t^*))\frac{d\hat{Z}}{dt}\frac{dt}{dn_E}$$

$$+\frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W - n\bar{\beta})D'(\hat{Z}(t^*)) + \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right] - \frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\frac{dt^*}{dn_E}.$$

Now, combining the term $dt^*/dn_E$ yields

$$\left[1-\frac{(1+\delta)n\bar{\beta}-(1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t^*))\frac{d\hat{Z}}{dt}+\frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt}-\frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right]\frac{dt^*}{dn_E}$$

$$=\frac{1+\delta}{\delta+\lambda_0}(\beta_E-\beta_W)D'(\hat{Z}(t^*))+\frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W-n\bar{\beta})D'(\hat{Z}(t^*))+\frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right].$$

That is,

$$\frac{dt^*}{dn_E}=\frac{\frac{1+\delta}{\delta+\lambda_0}(\beta_E-\beta_W)D'(\hat{Z}(t^*))+\frac{\frac{1}{n}(\delta+1)}{(\delta+\lambda_0)^2}\left[(n\beta_W-n\bar{\beta})D'(\hat{Z}(t^*))+\frac{d\hat{\Pi}/dt}{d\hat{Z}/dt}\right]}{1-\frac{(1+\delta)n\bar{\beta}-(1-\lambda_0)n\beta_W}{\delta+\lambda_0}D''(\hat{Z}(t^*))\frac{d\hat{Z}}{dt}+\frac{1-\lambda_0}{\delta+\lambda_0}\frac{\frac{d^2\hat{\Pi}}{dt}\frac{d\hat{Z}}{dt}-\frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}}.$$

Note that the denominator is exactly $\frac{d\Omega}{dt}$ as we derived earlier:

$$\frac{d\Omega}{dt}\equiv 1-n\bar{\beta}D''(\hat{Z})\frac{d\hat{Z}}{dt}+\frac{1-\lambda_0}{\delta+\lambda_0}\left((n\beta_W-n\bar{\beta})D''(\hat{Z})\frac{d\hat{Z}}{dt}+\frac{\frac{d^2\hat{\Pi}}{dt^2}\frac{d\hat{Z}}{dt}-\frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right)>0,$$

and the second term in the numerator can be rewritten from equation (C1) as

$$\left[(n\beta_W-n\bar{\beta})D'(\hat{Z})+\frac{d\hat{\Pi}}{d\hat{Z}}\right]=-\frac{\delta+\lambda_0}{1-\lambda_0}\left[t-n\bar{\beta}D'(\hat{Z})\right]=-\frac{n}{n_W}(\delta+\lambda_0)\left[t-n\bar{\beta}D'(\hat{Z})\right].$$

Therefore,

$$\frac{dt^*}{dn_E}=\frac{\frac{1+\delta}{\delta+\lambda_0}(\beta_E-\beta_W)D'(\hat{Z})-\frac{1+\delta}{(\delta+\lambda_0)}\frac{1}{n_W}\left[t-n\bar{\beta}D'(\hat{Z})\right]}{\frac{d\Omega}{dt}},$$

or

$$\frac{dt^*}{dn_E}=\frac{\frac{1+\delta}{\delta+\lambda_0}\frac{1}{n_W}\left[n_W(\beta_E-\beta_W)D'(\hat{Z})-\left(t-n\bar{\beta}D'(\hat{Z})\right)\right]}{\frac{d\Omega}{dt}}.$$

□

# D Proof of Lemma 2

*Proof.* The first-order condition of (8) with respect to $t$ yields

$$\frac{d\hat{G}_C(t)}{dt}=\frac{dJ_C}{dt}+\delta\frac{dJ}{dt}=0.$$

That is,

$$-\hat{Y}+\hat{Q}+\frac{n_C}{n}\left[\hat{Y}-\hat{Q}+t\frac{d\hat{Z}}{dt}\right]-n_C\beta_C D'(\hat{Z})\frac{d\hat{Z}}{dt}+\delta\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}=0,$$

which can be further simplified to

$$\frac{n_C}{n}\left[\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}+\left(\frac{n}{n_C}-1\right)\frac{d\hat{\Pi}}{dt}+(n\bar{\beta}-n\beta_C)D'(\hat{Z})\frac{d\hat{Z}}{dt}\right]+\delta\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}=0.$$

Define $\lambda_C=\frac{n_C}{n}$ as the fraction of the population that belongs to the organized industrial lobby group, then we have

$$\frac{d\hat{G}_C(t)}{dt}=(\lambda_C+\delta)\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}+\lambda_C\left[\frac{1-\lambda_C}{\lambda_C}\frac{d\hat{\Pi}}{dt}+(n\bar{\beta}-n\beta_C)D'(\hat{Z})\frac{d\hat{Z}}{dt}\right]=0,$$

or

$$\frac{\frac{d\hat{G}_C(t)}{dt}}{(\lambda_C+\delta)\frac{d\hat{Z}}{dt}}=\Omega_C\equiv\left(t-n\bar{\beta}D'(\hat{Z})\right)+\frac{\lambda_C}{\lambda_C+\delta}\left[(n\bar{\beta}-n\beta_C)D'(\hat{Z})+\frac{1-\lambda_C}{\lambda_C}\frac{d\hat{\Pi}}{d\hat{Z}}\right]=0.$$

Note that for $t^C$ to be a maximum, we need to ensure that the second-order condition is negative, i.e.,

$$\frac{d^2\hat{G}_C(t)}{dt^2}=(\lambda_C+\delta)\frac{d^2\hat{Z}}{dt^2}\Omega_C+(\lambda_C+\delta)\frac{d\hat{Z}}{dt}\frac{d\Omega_C}{dt}<0.$$

Since $\Omega_C=0$ and $\frac{d\hat{Z}}{dt}<0$, we must have

$$\frac{d\Omega_C}{dt}=1-n\bar{\beta}D''(\hat{Z})\frac{d\hat{Z}}{dt}+\frac{\lambda_C}{\delta+\lambda_C}\left((n\bar{\beta}-n\beta_C)D''(\hat{Z})\frac{d\hat{Z}}{dt}+\frac{1-\lambda_C}{\lambda_C}\frac{\frac{d^2\hat{\Pi}}{dt^2}\frac{d\hat{Z}}{dt}-\frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right)>0.$$

Similarly, the first-order condition of (9) with respect to $t$ yields

$$\frac{d\hat{G}_E(t)}{dt}=\frac{dJ_E}{dt}+\delta\frac{dJ}{dt}=0.$$

That is,

$$\frac{n_E}{n}\left[\hat{Y}-\hat{Q}+t\left(\frac{d\hat{Y}}{dt}-\frac{d\hat{Q}}{dt}\right)\right]-n_E\beta_E D'(\hat{Z})\left(\frac{d\hat{Y}}{dt}-\frac{d\hat{Q}}{dt}\right)+\delta\left(t-n\bar{\beta}D'(\hat{Z})\right)\left(\frac{d\hat{Y}}{dt}-\frac{d\hat{Q}}{dt}\right)=0.$$

Define $\lambda_E=\frac{n_E}{n}$ as the fraction of the population that belongs to the organized environmental lobby group, then

$$\lambda_E\left[-\frac{d\hat{\Pi}}{dt}+\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}+(n\bar{\beta}-n\beta_E)D'(\hat{Z})\frac{d\hat{Z}}{dt}\right]+\delta\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}=0,$$

or

$$\frac{d\hat{G}_E(t)}{dt}=(\lambda_E+\delta)\left(t-n\bar{\beta}D'(\hat{Z})\right)\frac{d\hat{Z}}{dt}-\lambda_E\left(\frac{d\hat{\Pi}}{dt}+(n\beta_E-n\bar{\beta})D'(\hat{Z})\frac{d\hat{Z}}{dt}\right)=0,$$

which implies that

$$\frac{\frac{d\hat{G}_E(t)}{dt}}{(\lambda_E+\delta)\frac{d\hat{Z}}{dt}} = \Omega_E \equiv \left(t - n\bar{\beta}D'(\hat{Z})\right) - \frac{\lambda_E}{\lambda_E+\delta}\left[(n\beta_E - n\bar{\beta})D'(\hat{Z}) + \frac{d\hat{\Pi}}{d\hat{Z}}\right] = 0.$$

Note that for $t^E$ to be a maximum, we need to ensure that the second-order condition is negative, i.e.,

$$\frac{d^2\hat{G}_E(t)}{dt^2} = (\lambda_E+\delta)\frac{d^2\hat{Z}}{dt^2}\Omega_E + (\lambda_E+\delta)\frac{d\hat{Z}}{dt}\frac{d\Omega_E}{dt} < 0.$$

Since $\Omega_E = 0$ and $\frac{d\hat{Z}}{dt} < 0$, we must have

$$\frac{d\Omega_E}{dt} = 1 - n\bar{\beta}D''(\hat{Z})\frac{d\hat{Z}}{dt} - \frac{\lambda_E}{\lambda_E+\delta}\left((n\beta_E - n\bar{\beta})D''(\hat{Z})\frac{d\hat{Z}}{dt} + \frac{\frac{d^2\hat{\Pi}}{dt^2}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2}\right) > 0.$$

□

# E Proof of Lemma 3 and Proposition 4

*Proof.* Given the specific functional forms and parameter values, we have

$$Y = F(\bar{K}, L) = 2L^{\frac{1}{2}}, \quad F_L(\bar{K}, L) = L^{-\frac{1}{2}}, \quad F_{LL}(\bar{K}, L) = -\frac{1}{2}L^{-\frac{3}{2}}, \quad \frac{F_{LL}}{F_L^3} = -\frac{1}{2},$$

and thus

$$u'(y) = A - y, \quad \eta'(Q) = Q, \quad D'(Z) = 1, \quad D''(Z) = 0,$$
$$\Gamma_E(m_C, m_E) = 1 > 0, \quad \Gamma_C(m_C, m_E) = -1 < 0,$$
$$\Gamma_{EE}(m_C, m_E) = \Gamma_{CC}(m_C, m_E) = \Gamma_{EC}(m_C, m_E) = 0,$$
$$c'_E(m_E) = m_E, \quad c'_C(m_C) = m_C, \quad c''_E(m_E) = c''_C(m_C) = 1.$$

From equation (1), the optimal exported waste can be expressed as

$$\hat{Q}(t) = t - \mu.$$

From equation (2): $(1-t)L^{-\frac{1}{2}} = 1$, we can obtain the optimal labour and thereby output in the manufacturing sector as

$$\hat{L}(t) = (1-t)^2, \quad \hat{Y}(t) = 2(1-t).$$

Therefore, the optimal pollution is given by

$$\hat{Z}(t) = \hat{Y}(t) - \hat{Q}(t) = 2(1-t) - (t-\mu) = 2 + \mu - 3t.$$

From equation (5): $u'(y) = A - y = 1$, the optimal consumption of manufactured good can be derived as

$$\hat{y} = A - 1.$$

To ensure $\hat{Y}, \hat{Q}, \hat{Z}, \hat{y} > 0$, we would need Assumption (A1):

$$0 < \mu < t < \frac{2+\mu}{3} < 1 < A.$$

Then, the aggregate profits and consumer surplus are given by

$$\begin{aligned}
\hat{\Pi}(t) &= (1-t)\,2(1-t) - (1-t)^2 + (t-\mu)(t-\mu) - \frac{1}{2}(t-\mu)^2, \\
&= (1-t)^2 + \frac{1}{2}(t-\mu)^2, \\
CS &= (A-1)\hat{y} - \frac{1}{2}\hat{y}^2 = (A-1)^2 - \frac{1}{2}(A-1)^2 = \frac{1}{2}(A-1)^2.
\end{aligned}$$

Clearly,

$$\begin{aligned}
\frac{d\hat{Y}(t)}{dt} &= -2 < 0, \quad \frac{d\hat{Q}(t)}{dt} = 1 > 0, \quad \frac{d\hat{Z}(t)}{dt} = -3 < 0, \\
\frac{d\hat{\Pi}(t)}{dt} &= \hat{Q} - \hat{Y} = t - \mu - 2(1-t) = 3t - \mu - 2 < 0, \\
\frac{d\hat{\Pi}}{d\hat{Z}} &= \frac{d\hat{\Pi}/dt}{d\hat{Z}/dt} = \frac{3t-\mu-2}{-3} = \frac{2+\mu}{3} - t > 0,
\end{aligned}$$

with

$$\frac{d^2\hat{\Pi}}{dt^2} = 3 > 0, \quad \frac{d^2\hat{Z}}{dt^2} = 0, \quad \frac{\frac{d^2\hat{\Pi}}{dt^2}\frac{d\hat{Z}}{dt} - \frac{d\hat{\Pi}}{dt}\frac{d^2\hat{Z}}{dt^2}}{(\frac{d\hat{Z}}{dt})^2} = \frac{3\times(-3) - 0}{(-3)^2} = -1 < 0.$$

The welfare functions of lobby groups are denoted by

$$\begin{aligned}
J_C(t) &= (1-t)^2 + \frac{1}{2}(t-\mu)^2 + n_C\left[\bar{l} + t(2-3t+\mu) + \frac{1}{2}(A-1)^2\right], \\
J_E(t) &= n_E\left[\bar{l} + t(2-3t+\mu) + \frac{1}{2}(A-1)^2 - (2-3t+\mu)\right], \\
J_W(t) &= n_W\left[\bar{l} + t(2-3t+\mu) + \frac{1}{2}(A-1)^2 - \beta_W(2-3t+\mu)\right],
\end{aligned}$$

and the social welfare is given by

$$J(t) = (1-t)^2 + \frac{1}{2}(t-\mu)^2 + \bar{L} + t(2-3t+\mu) + \frac{1}{2}(A-1)^2 - (n_E + n_W\beta_W)(2-3t+\mu).$$

Given these functional forms and parameter values, the political taxes defined by

(C1), (C2) and (C3) can be solved as

$$t^* = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W\big) - (1-n_C-n_E)(2+\mu)}{3\,(\delta - 1 + 2n_C + 2n_E)}, \tag{20}$$

$$t^C = \frac{3\big(\delta n_E + \delta n_W \beta_W\big) - (1-n_C)\,(2+\mu)}{3(\delta - 1 + 2n_C)}, \tag{21}$$

$$t^E = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W\big) + n_E(2+\mu)}{3(\delta + 2n_E)}. \tag{22}$$

It follows that

$$\frac{dt^*}{d\beta_W} = \frac{\delta n_W}{\delta - 1 + 2n_C + 2n_E}, \quad \frac{dt^C}{d\beta_W} = \frac{\delta n_W}{\delta - 1 + 2n_C}, \quad \frac{dt^E}{d\beta_W} = \frac{\delta n_W}{\delta + 2n_E}.$$

To ensure the existence of these optimal taxes, we need the second-order conditions of $\hat{G}(t)$, $\hat{G}_C(t)$ and $\hat{G}_E(t)$ with respect to $t$ are negative, or equivalently

$$\frac{d\Omega}{dt} > 0, \quad \frac{d\Omega_E}{dt} > 0, \quad \frac{d\Omega_C}{dt} > 0.$$

That is, we need to ensure

$$\begin{aligned}
\frac{d\Omega}{dt} &= 1 - \frac{1-n_C-n_E}{\delta + n_C + n_E} = \frac{\delta - 1 + 2n_C + 2n_E}{\delta + n_C + n_E} > 0,\\
\frac{d\Omega_E}{dt} &= 1 + \frac{n_E}{n_E + \delta} > 0,\\
\frac{d\Omega_C}{dt} &= 1 - \frac{1-n_C}{\delta + n_C} = \frac{\delta - 1 + 2n_C}{\delta + n_C} > 0.
\end{aligned}$$

Since $\delta - 1 + 2n_C + 2n_E > \delta - 1 + 2n_C$, it is sufficient to ensure the positivity of the above conditions if $\delta - 1 + 2n_C > 0$, or Assumption (A2):

$$\delta > 1 - 2n_C.$$

From the first-order conditions of lobby groups' problem with respect to messages in (12) and (13), we have

$$\begin{aligned}
\frac{\partial \mathcal{L}_E(m_C, m_E)}{\partial m_E} &= \delta n_W \big(\hat{Z}(t^C) - \hat{Z}(t^*)\big) - m_E\\
&= 3\delta n_W (t^* - t^C) - m_E = 0, 
\end{aligned} \tag{23}$$

$$\begin{aligned}
\frac{\partial \mathcal{L}_C(m_C, m_E)}{\partial m_C} &= -\delta n_W \big(\hat{Z}(t^E) - \hat{Z}(t^*)\big) - m_C\\
&= 3\delta n_W (t^E - t^*) - m_C = 0.
\end{aligned} \tag{24}$$

Equations (23) and (24) indicate that

$$t^E > t^* > t^C.$$

Substituting (20), (21) and (14) into (23) yields $m_E$ as a function of $m_C$:

$$m_E(m_C) = \frac{\delta n_W \left[ 3n_E\big(\delta(1-2n_E) - 1 + 2n_C\big) + (2+\mu)(1+\delta)n_E - 6n_E\delta n_W(\beta_0 - m_C) \right]}{(\delta - 1 + 2n_C)\,(\delta - 1 + 2n_C + 2n_E) + 6n_E(\delta n_W)^2}, \tag{25}$$

with

$$\frac{dm_E(m_C)}{dm_C} = \frac{6n_E(\delta n_W)^2}{(\delta - 1 + 2n_C)\,(\delta - 1 + 2n_C + 2n_E) + 6n_E(\delta n_W)^2} > 0,$$

i.e., as $m_C$ increases, $m_E$ also goes up. Similarly, substituting (20), (22) and (14) into (24) yields $m_C$ as a function of $m_E$:

$$m_C(m_E) = \frac{\delta n_W \left[ 3\big((1+\delta)n_E + \delta n_W(\beta_0 + m_E)\big)(2n_C - 1) + (2+\mu)(\delta + n_E - \delta n_C) \right]}{(\delta + 2n_E)\,(\delta - 1 + 2n_C + 2n_E) + 3(\delta n_W)^2(2n_C - 1)}, \tag{26}$$

with

$$\frac{dm_C(m_E)}{dm_E} = \frac{3(\delta n_W)^2(2n_C - 1)}{(\delta + 2n_E)\,(\delta - 1 + 2n_C + 2n_E) + 3(\delta n_W)^2(2n_C - 1)}.$$

Note that for $(m_E^*, m_C^*)$ to be the maximum solutions, we need to ensure that the respective second-order conditions are negative. Notice that

$$\begin{aligned}
\frac{\partial^2 \mathcal{L}_E(m_C, m_E)}{\partial m_E^2} &= -1 + \delta n_W(-3)\left[\frac{\delta n_W}{\delta - 1 + 2n_C} - \frac{\delta n_W}{\delta - 1 + 2n_C + 2n_E}\right] \\
&= -1 - 3(\delta n_W)^2 \frac{2n_E}{(\delta - 1 + 2n_C)(\delta - 1 + 2n_C + 2n_E)} < 0,
\end{aligned}$$

which is automatically satisfied. But for

$$\begin{aligned}
\frac{\partial^2 \mathcal{L}_C(m_C, m_E)}{\partial m_C^2} &= -1 + \delta n_W(-3)\left[\frac{\delta n_W}{\delta + 2n_E} - \frac{\delta n_W}{\delta - 1 + 2n_C + 2n_E}\right] \\
&= -1 - 3(\delta n_W)^2 \frac{-1 + 2n_C}{(\delta + 2n_E)(\delta - 1 + 2n_C + 2n_E)} < 0,
\end{aligned}$$

we would need Assumption (A3):

$$(\delta + 2n_E)(\delta - 1 + 2n_C + 2n_E) + 3(\delta n_W)^2(2n_C - 1) > 0.$$

Therefore,

(a) If $n_C > \frac{1}{2}$, then (A3) is automatically satisfied. In this case,

$$\frac{dm_C(m_E)}{dm_E} > 0,$$

i.e., as $m_E$ increases, $m_C$ also increases.

(b) However, if $n_C < \frac{1}{2}$, then we have

$$\frac{dm_C(m_E)}{dm_E} < 0,$$

i.e., as $m_E$ goes up, $m_C$ decreases. But (A3) further indicates that

$$n_C > \frac{1}{2} - \frac{1}{2}\frac{(\delta+2n_E)^2}{(\delta+2n_E)+3(\delta n_W)^2}.$$

That is, we need

$$\frac{1}{2} - \frac{1}{2}\frac{(\delta+2n_E)^2}{(\delta+2n_E)+3(\delta n_W)^2} < n_C < \frac{1}{2}.$$

Using (25) and (26), we can solve the pair of the equilibrium number of messages $(m_E^*, m_C^*)$ as

$$m_E^* = \frac{\chi^*}{\xi^*}, \quad m_C^* = \frac{\phi^*}{\xi^*},$$

where

$$\begin{aligned}
\xi^* &= \Big[(\delta-1+2n_C)(\delta+2n_E)\,(\delta-1+2n_C+2n_E)\Big] + 3(\delta n_W)^2\Big[2n_E(2n_E+\delta)+(2n_C-1)(\delta-1+2n_C)\Big],\\
\chi^* &= \Big[\delta n_W n_E\Big(3(\delta n_W)^2+(1+\delta)(\delta+2n_E)\Big)\Big](2+\mu) - \Big[6(\delta n_W)^2 n_E(\delta+2n_E)\Big]\beta_0\\
&\quad + \Big[3\delta n_W\Big(3(\delta n_W)^2(2n_C-1)-(\delta+2n_E)(1-2n_C+\delta(2n_E-1))\Big)\Big]n_E,\\
\phi^* &= \Big[\delta n_W\Big(\delta(1-n_C)(\delta-1+2n_C)+n_E(\delta-1+2n_C+3(\delta n_W)^2)\Big)\Big](2+\mu)\\
&\quad + \Big[3(\delta n_W)^2\,(2n_C-1)\,(\delta-1+2n_C)\Big]\beta_0 + \Big[3\delta n_W\,(2n_C-1)\Big(2n_C-1+\delta\,(2n_C+\delta+3\delta n_W^2)\Big)\Big]n_E.
\end{aligned}$$

Since by Assumption (A3),

$$(\delta+2n_E)(\delta-1+2n_C+2n_E)+3(\delta n_W)^2(2n_C-1) > 0,$$

and by Assumption (A2),

$$\delta-1+2n_C > 0,$$

it follows that

$$(\delta-1+2n_C)(\delta+2n_E)\,(\delta-1+2n_C+2n_E)+3(\delta n_W)^2(2n_C-1)(\delta-1+2n_C) > 0,$$

and thus $\xi^* > 0$. To ensure the optimal number of messages is positive, we need to make Assumption (A4):

$$\chi^* > 0, \quad \phi^* > 0.$$

Then, the equilibrium posterior environmental valuation by workers is given by

$$\beta_W^* = \beta_0 + m_E^* - m_C^* = \frac{\beta_0 \xi^* + \chi^* - \phi^*}{\xi^*}$$

and thus the equilibrium taxes are

$$t_{eq}^* = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W^*\big) - (1-n_C-n_E)(2+\mu)}{3\,(\delta - 1 + 2n_C + 2n_E)},$$

$$t_{eq}^C = \frac{3\big(\delta n_E + \delta n_W \beta_W^*\big) - (1-n_C)\,(2+\mu)}{3(\delta - 1 + 2n_C)},$$

$$t_{eq}^E = \frac{3\big((1+\delta)n_E + \delta n_W \beta_W^*\big) + n_E(2+\mu)}{3(\delta + 2n_E)}.$$

Therefore, the equilibrium political contributions to the environmental and industrial lobby groups are given by

$$\psi_E^*(t_{eq}^*, t_{eq}^C) = \Big[J_C(t_{eq}^C) + \delta J(t_{eq}^C)\Big] - \Big[J_C(t_{eq}^*) + \delta J(t_{eq}^*)\Big],$$

$$\psi_C^*(t_{eq}^*, t_{eq}^E) = \Big[J_E(t_{eq}^E) + \delta J(t_{eq}^E)\Big] - \Big[J_E(t_{eq}^*) + \delta J(t_{eq}^*)\Big].$$

□

# F Proof of Propositions 5 and 6

*Proof.* Given the set of parameter values, (A1)–(A4) implies that

$$0 < \mu < 1, \quad \delta > 1, \quad m_E^* > 0, \quad m_C^* > 0.$$

The derivatives of $m_E^*, m_C^*, \beta_W^*, \psi_E^*, \psi_C^*, t_{eq}^*$ and $Q^*$ with respect to $\beta_0$ are respectively given by:

$$\frac{\partial m_E^*}{\partial \beta_0} = -\frac{3\delta(1+\delta)}{2(2+\delta)(2\delta-1)} < 0, \qquad \frac{\partial m_C^*}{\partial \beta_0} = -\frac{3\delta(\delta-1)}{2(2+\delta)(2\delta-1)} < 0,$$

$$\frac{\partial \psi_E^*}{\partial \beta_0} = -\frac{2(\delta+1)(\delta-1)m_E^*}{\delta(2+\delta)(2\delta-1)} < 0, \qquad \frac{\partial \psi_C^*}{\partial \beta_0} = -\frac{2(\delta+1)(\delta-1)m_C^*}{\delta(2+\delta)(2\delta-1)} < 0.$$

$$\frac{\partial \beta_W^*}{\partial \beta_0} = \frac{2(\delta+1)(\delta-1)}{(2+\delta)(2\delta-1)} > 0, \qquad \frac{\partial t_{eq}^*}{\partial \beta_0} = \frac{\partial Q^*}{\partial \beta_0} = \frac{(\delta+1)(\delta-1)}{(2+\delta)(2\delta-1)} > 0.$$

Similarly, we have

$$\frac{\partial m_E^*}{\partial \mu} = \frac{7\delta^2 + 8\delta + 4}{8(2+\delta)(2\delta-1)} > 0, \qquad \frac{\partial m_C^*}{\partial \mu} = \frac{11\delta^2 - 4\delta - 4}{8(2+\delta)(2\delta-1)} > 0,$$

$$\frac{\partial \psi_E^*}{\partial \mu} = \frac{(\delta-1)(7\delta^2+8\delta+4)m_E^*}{6\delta^2(2+\delta)(2\delta-1)} > 0, \qquad \frac{\partial \psi_C^*}{\partial \mu} = \frac{(1+\delta)(11\delta^2-4\delta-4)m_C^*}{6\delta^2(2+\delta)(2\delta-1)} > 0,$$
$$\frac{\partial \beta_W^*}{\partial \mu} = \frac{-\delta^2+3\delta+2}{(2+\delta)(2\delta-1)}, \qquad \frac{\partial t_{eq}^*}{\partial \mu} = \frac{(2-\delta)(3\delta^2+\delta+2)}{12\delta(2+\delta)(2\delta-1)},$$
$$\frac{\partial Q^*}{\partial \mu} = -\frac{27\delta^3+31\delta^2-24\delta-4}{12\delta(2+\delta)(2\delta-1)} < 0,$$

where $\frac{\partial \beta_W^*}{\partial \mu}$ is positive for $1 < \delta \leq \bar{\delta} \equiv \frac{3+\sqrt{17}}{2}$ and negative for $\delta > \bar{\delta}$, and $\frac{\partial t_{eq}^*}{\partial \mu}$ is positive for $1 < \delta < 2$ and negative for $\delta > 2$.

□