ESSAYS ON POLITICAL ECONOMY IN TRADE AND ENVIRONMENT

by

SHINYA KAWAHARA

M.A., The University of British Columbia, 1999
M.A., Nagoya University, 1998
B.A., Nagoya University, 1996

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Economics)

THE UNIVERSITY OF BRITISH COLUMBIA

July 2006

Abstract

This thesis consists of three essays that contribute to international trade and environmental economics. The first essay addresses the question of why some countries fail to adopt environmental policies that are sufficiently strong, while others adopt policies that are too stringent. Constructing a political economy model in which voters face uncertainty due to types of politicians and the risk of environmental damage, it demonstrates that there is an equilibrium in which a politician uses a weaker environmental policy rather than efficient direct transfers for redistribution. It also shows that there is an equilibrium in which a stricter environmental policy can be implemented by a politician who has no incentive to make transfers. Then, the latter equilibrium in which a too stringent environmental policy emerges is shown to be more plausible unless the incumbent's initial reputation is sufficiently strong.

The second essay questions how one country's decision to liberalize trade affects a political economic structure that determines environmental policy in other country. By constructing a political economy model with endogenous lobby formation, it shows that unilateral tariff reductions (UTRs) by a large country importing a dirty good will generate an industry lobby that demands a lax environmental regulation in a small country exporting that good. Then, it shows that for a pre-existing lobby, the UTRs cause the formation of a lobby group that opposes initially distorted environmental policy in the small country. Numerical simulations show that the UTRs first cause the formation of industry lobby groups and further reductions of trade barriers will generate an environmental lobby in the small country.

The third essay examines what the successful scenarios for the environmental policy reforms should look like when they have an impact on the terms of trade. By setting up a general equilibrium model of international trade that is extended to include environmental externalities, it characterizes and compares the welfare-improving reforms of environmental taxes and standards in a large open economy. It also considers the case in which there are multiple rather than single pollutants in the economy to examine how a reform of one pollutant affects other remaining pollutants.

Table of Contents

List of Figures

Acknowledgement

First and foremost I would like to thank my thesis supervisor Professor Brian Copeland for his never ended support throughout my graduate study at the University of British Columbia. Without his continuing guidance and encouragement, this thesis could not be made possible. I am indebted to my thesis committee members, Professor Patrick Francois and Professor Sumeet Gulati, for their continuing help and advice that started from the first day of this thesis and never stopped until the end of the thesis. I have to acknowledge their invaluable help in all chapter of this thesis. I gratefully acknowledge the precious comments and suggestions from the university examiners, Professor Hugh Neary and Professor Ralph Winter, and the external examiner Professor Ramon Lopez at the University of Maryland. Finally, I am grateful to Professor James Brander and Professor Kevin Milligan for being the chair of my thesis defense.

To my parents, Masamichi and Masako Kawahara

Chapter 1

Overview and Summary

Sustainable development – promoting economic growth and trade liberalization with positive impact on environment – has become one of the central concerns in modern society.[1] Trade liberalization will enhance economic growth by expanding a country's economic activity, but this may increase the total amount of pollution generated unless an appropriate pollution abatement program is in place. Or, introducing stringent environmental regulations on pollutants generated during production will cause a competitive loss for a domestic product compared to an imported one. Moreover, excessive environmental protectionism may be abused as secondary barriers to trade, which will break down the already established multilateral trading system. To overcome those situations, it is very important to understand the linkages between environmental and trade policies: how those policies should impact international trade and the environmental quality, what determines those policies, and how they interact with each other.

The purpose of this thesis is to analyze linkages between trade and environment in the context of political economy. The thesis consists of three essays that investigate three specific questions on this issue. The first question considers why some governments fail to adopt environmental policies that are sufficiently strong, while others adopt policies that seem too stringent. Those two opposing situations can be described by two types of equilibrium in a two-period signaling game in which voters face uncertainties as to (1) environmental damages and (2) policymaker's objectives. The second issue addressed is why political pressure to reduce environmental regulation is so strong in the earlier stages of trade and growth, and how moving toward free trade can generate a political pressure that demands strin-

[1]The recent decision by the General Agreements on Tariffs and Trade (GATT) and its successor the World Trade Organization (WTO) on establishing the Committee on Trade and Environment (CTE) to discuss issues relating to trade and environment reflects this. It also represents the key concern in the recent policy debates on the multilateral environmental agreements (MEAs) such as the Montreal Protocol for the protection of ozone layer, the Basel Convention on the trade of hazardous waste across borders, and the Kyoto Protocol to reduce human-induced emissions of greenhouse gases. Details for recent policy debates on international trade and the environment can be found in Esty (1994).

gent environmental regulation. The third question considers what the successful scenarios for the environmental protection programs should look like when they have an impact on international prices of commodities.

The first essay examines why differences emerge among governments in the environmental regulations they choose. Constructing a political economy model in which voters face uncertainty due to types of politicians and the risk of environmental damage, this essay explains why some governments choose weak environmental regulations while others select overly strict environmental regulations. It is demonstrated that there is a pooling equilibrium in which a politician uses a weaker environmental policy rather than efficient direct transfers for redistribution. It is also shown that there is a separating equilibrium in which a stricter environmental policy can be implemented by a politician who has no incentive to make transfers. Then it discusses which equilibrium should be more plausible and concludes that the latter equilibrium in which a too stringent environmental policy emerges can dominate the former unless the incumbent's initial reputation is sufficiently strong.

The second essay questions how one country's decision to liberalize trade affects a political economic structure that determines environmental policy in other country. By constructing a political economy model in which formation of lobby groups and environmental policy are endogenously determined, the second essay shows that unilateral tariff reductions by a large country importing a dirty good will generate an industry lobby that demands a lax environmental regulation in a small country exporting that good. Then, it is shown that for a pre-existing lobby, unilateral tariff reductions cause the formation of a lobby group that opposes initially distorted environmental policy in the small country. Finally, numerical simulations show that the unilateral tariff reductions first cause the formation of industry lobby groups and further reductions of trade barriers will generate an environmental lobby in the small country. These results are consistent with the political forces behind the inverse U-shaped relationship between trade, growth and the environment known as the Environmental Kuznets Curve.

The third essay studies welfare-improving reforms of environmental policies in a large open economy. By setting up a general equilibrium model of international trade that is

extended to include environmental externalities, the third essay characterizes and compares the reforms of both environmental taxes and standards. It also considers the case in which there are multiple rather than single pollutants in the economy and examines how a reform of one pollutant should have an impact on other remaining pollutants.

Chapter 2

Environmental Policy as a Politically Optimal Choice for Electoral Competition

2.1 Introduction

Environmental protection has become a central issue on the public agenda over the last several decades. Improved scientific understanding has revealed the seriousness of environmental effects of exposure to pollutants, and economic growth has led to increased demand for environmental quality via income effects. Consequently, governments face numerous pressures to implement cost-effective environmental policy.

However, governments seem to face a great deal of difficulty in adopting an appropriate level of environmental regulation. In some cases, environmental regulations seem to be far too lax, whereas in other cases, they are too stringent. For example, many of the existing plans to regulate the U.S. fisheries are thought to be inadequate to maintain sustainable fish stocks.[2] Similarly, a number of state governments in the U.S. insufficiently address groundwater overdrafting problems.[3] These are both examples of cases where policy is too lax. On the other hand, mandatory vehicle inspection and maintenance programs in North America routinely fail a cost-benefit test - they fail to generate environmental benefits sufficient to cover their costs.[4] Similarly, several recycling programs such as mandatory deposit-refund systems do not generate enough recycling revenues and environmental benefits to offset their cost of the program.[5] These can be thought of as examples of policies in which environmental

[2] See Thompson (2000) for a detailed discussion on this issue.

[3] See also Thompson (2000) for a detailed discussion on this issue.

[4] Beaton et al. (1995) examine California's case, Hubbart (1997) discusses 1990 Clean Air Act Amendments (CAAA) and Coninx (1998) discusses British Columbia's Air Care inspection program.

[5] Dewees and Hare (1998) give a good survey on the cost-effectiveness of the deposit-refund system and

regulations are too stringent.

This essay develops a model of political economy that explains the above situations. In particular, using a political economic framework, it provides one explanation for the question of why some governments fail to adopt policies that are sufficiently strong, while others adopt policies that are too stringent. This study claims that the existence of uncertainties with respect to (1) environmental damages and (2) policymaker's objectives can explain the emergence of environmental policy that deviates from the optimum. It will be shown that when an incumbent's reputation is sufficiently weak, we are more likely to see the emergence of an environmental policy that is too stringent rather than one which is too weak.

Two situations that show the two types of equilibrium are described using a version of the two-period signaling game. In the first type of equilibrium, a politician who wants to protect industry profit implements an environmental policy that is too weak. This equilibrium is characterized as a pooling equilibrium of the game. In the second type of equilibrium, a politician who cares only about social welfare implements a too stringent environmental policy to separate himself from the previous type of politician. This equilibrium is characterized as a separating equilibrium of the game.

The model described is a version of the two-period signaling game in which voters face two types of uncertainties. The first uncertainty concerns the types of politicians. There are two types of politicians; "pro-welfare" and "pro-industry". The pro-welfare politician cares about the aggregate social welfare, while the pro-industry politician cares about special interests who gain from lax environmental policy. Voters cannot observe the types of politicians. The second uncertainty concerns the environmental damages from the production of a certain good. Voters do not know how risky the environmental damage is that they might suffer. Firstly, in a pooling equilibrium in which a too weak environmental policy is implemented by a pro-industry politician, the pro-industry politician exploits uncertainty over environmental damages and sets too low an environmental tax that benefits special interests. This describes many governments' behavior of not adopting stringent environmental regulations, such as the U.S. regulations towards fisheries and groundwater.

other recycling programs such as curbside recycling in North America.

Second, in a separating equilibrium in which too strict an environmental policy is adopted by a pro-welfare politician, the pro-welfare politician adopts too high an environmental tax as a way to separate himself from the pro-industry politician and hence win the election. This describes the above government's behavior of implementing tougher environmental regulations, such as the mandatory vehicle I/M and the recycling programs in North America. Then, in the discussion about which equilibrium should be more plausible, it can be shown that if the incumbent's initial reputation is sufficiently low the pooling equilibrium is dominated by the separating equilibrium. Thus, characterizing the above two types of equilibria, this essay provides a unified framework that can be used to explain two sides of a government's behavior towards environmental regulations.

This essay is related to two groups of literature. The first, including Fredriksson (1997), Aidt (1998), and Schleich (1999), examines an inefficient environmental policy by applying the model of special interest politics developed by Grossman and Helpman (1994). They show that a politically-motivated government has an incentive to distort its environmental policy choice to help special interests.[6] A critical feature of those studies is that the environmental policy can be used as an indirect way of transferring resources to special interests. However, environmental policy is not an efficient instrument to do so. In particular, a government can potentially use a more efficient instrument such as a lump-sum transfer for this purpose rather than using environmental policy. Once such an instrument is available, the predictions those studies can generate will be substantially weakened. On the other hand, this essay includes direct transfers as an additional (and more efficient) instrument and examines whether inefficient environmental policy can still be adopted as a way for income redistribution.

The second literature group investigates inefficient policy choices by applying a Coate and Morris (1995) type of political economy model. Brett and Keen (2000) study the earmarking of environmental taxes in a model in which voters are uncertain about the motivations of

[6]Indeed, a number of studies examine this issue by focusing on various kinds of government motivations to protect local interests. According to Copeland and Taylor (2004), there are three motives for protections a government tends to have to protect local interests; (1) terms of trade motives, (2) strategic motives, and (3) political economy motives.

politicians. Sturm (2001) studies trade disputes over product standards in a model where voters face both politician and policy uncertainties. However these studies, as Coate and Morris (1995) do, focus only on the pooling equilibrium and hence on the pro-industry politician's inefficient behavior. On the other hand, this essay examines the separating as well as the pooling equilibria to focus on the pro-welfare politician's behavior.

The essay is organized as follows. The next section describes the model and defines the game and the equilibrium. Section 2.3 solves the game and examines the equilibrium behaviors. Section 2.4 characterizes the equilibria and discusses the equilibrium selections. The final section concludes the essay.

2.2 The Model

This section sets up a political economy model with asymmetric information that will be used throughout the analysis. The model is based on a framework developed by Coate and Morris (1995). Consider a small open economy that lasts for two periods. In each period, a politician in office decides the level of environmental regulation. The environmental regulation takes the form of taxing the production of some pollution-generating good, which is called a pollution tax. The appropriate level of a pollution tax benefits citizens at the cost of industry profits. The industry profits are incomes for holders of some specific factors of production, called special interests. In addition to environmental policy, the politician decides whether to undertake direct cash transfers to the special interests. At the end of the first period, there is an election in which the incumbent faces a randomly selected challenger. The citizens alone can determine the outcome of the election. In the second period, the winner of the election chooses the environmental policy and the direct transfers in that period.

The economy has two sectors. One sector produces a non-polluting numeraire good z and the other sector produces a good x, the production of which generates pollution which negatively affects the citizen's utility.[7] There are four types of agents in the economy; citizen, special interests, incumbent politician, and the challenger.

[7]Here the production externality is simply ruled out so that the production of good x does not affect the productivity.

2.2.1 Production

The production side of the economy is represented by a simple specific factors model of a small open economy that is frequently used in the theory of international trade.[8] The non-polluting numeraire good z is produced by labor alone with constant returns to scale technology. The input-output coefficient is assumed to be one. The polluting good x is produced by labor and an inelastically supplied specific factor with constant returns to scale technology. Provided that both goods are produced in equilibrium, the equilibrium wage rate becomes equal to one, and hence the supply of good x depends only on its producer price p. Note that the production of good x is subject to the pollution tax t so that $p = p^* - t$, where p^* is the world price of good x and is assumed to be constant from the small country assumption. Thus, the supply function of good x can be written as $x(t)$. The reward to the specific factor also depends only on p (and hence t) and can be written as $\pi(t)$. Application of the envelope theorem gives the relationship, $\pi' = -x$.

2.2.2 Citizens

In each period, citizens supply labor inelastically and obtain labor income. Then, they spend their income on consumption of two goods. Also, they care about the environment. Their per-period utility function is given by $u_c = c_z + u(c_x) - h(\eta, x)$, where c_z and c_x denotes the consumption of goods z and x, respectively. The function h represents environmental damage caused by production of good x. It depends positively on the amount of production of x, and on the unknown parameter η. The parameter η represents the risk of environmental damage that the production of good x causes. Details of η will be discussed later. The sub-utility function $u(\cdot)$ is assumed to be increasing and strictly concave. Their per-period choice of c_z and c_x can be summarized by the following optimization problem.

$$\max_{c_z, c_x} u_c = c_z + u(c_x) - h(\eta, x),$$

$$s.t.\ y_c = c_z + p^* c_x,$$

[8] For a detailed discussion of the specific factors model, see Dixit and Norman (1980), and Woodland (1982).

where y_c is the per-period net income for a citizen. From the first order conditions, the demand for good x can be obtained as

$$c_x = c_x(p^*),$$

where the function $c_x(\cdot)$ is the inverse of $u'(\cdot)$. The demand for good z is

$$c_z = y_c - p^* c_x(p^*).$$

Thus, the per-period indirect utility function for the citizen can be obtained by substituting these into u_c.

$$v_c = y_c + s - h(\eta, x), \tag{1}$$

where $s = u\left[c_x(p^*)\right] - p^* c_x(p^*)$ represents the consumer surplus and is constant for a fixed world price p^*.

2.2.3 Special Interests

Special interests are owners of the specific factor used in the production of good x. In each period, they supply this factor inelastically and obtain its reward. Unlike the citizens, they do not care about the environment.[9] Their per-period utility function is given by $u_s = c_z + u(c_x)$. Their per-period choice of c_z and c_x can be summarized by the following optimization problem.

$$\max_{c_z, c_x} u_s = c_z + u(c_x),$$

$$s.t.\ y_s = c_z + p^* c_x,$$

[9]This assumption is just for simplicity. In fact, it is possible to have special interests caring about the environment. The important point is that they also care about industry profits and hence want less strict environmental regulation than the citizens.

where y_s is the per-period net income for a special interest. As before, the per-period indirect utility function for the special interest can be obtained as

$$v_s = y_s + s. \tag{2}$$

2.2.4 Net Incomes and Indirect Utilities

The economy consists of many identical citizens and special interests. The total number of the population is normalized to one. Let α_c and α_s denote the fraction of the citizens and the special interests in the total population, respectively.[10] Let l be the total endowment of labor in each period. As both goods are assumed to be produced in equilibrium, the per capita labor income each citizen receives in each period is l/α_c. The special interest obtains the reward to the specific factor as an owner of that factor. Assuming that the ownership of the specific factor is entirely symmetric, each special interest receives an amount of π/α_s as a factor income. The direct income transfers to the special interests τ are financed by lump-sum taxation of the citizens.[11] Thus, if a politician decides to undertake the direct transfer of an amount τ, the amount of taxes each citizen has to pay is τ/α_c and each special interest receives τ/α_s as a transfer income. Revenue from pollution taxes can be written as

$$r(t) = tx(t),$$

which is assumed to be uniformly rebated to the citizens.[12]

Therefore, the per-period net income for a citizen and a special interest can be written

[10] Thus, $\alpha_c + \alpha_s = 1$.

[11] Focusing on the case where $\tau \geq 0$, that is the direct income transfers are only made from the special interests to the citizens, the question of how environmental policy can be used as a substitute for direct transfers to the special interests, not to the citizens can be examined.

[12] Again, this is for simplicity, and it is still possible to have special interests obtaining the tax revenue. The important point is that they also care about industry profits and hence want a less strict environmental regulation than the citizens.

as, respectively;

$$y_c = [l + r(t) - \tau]/\alpha_c, \tag{3}$$

$$y_s = [\pi(t) + \tau]/\alpha_s. \tag{4}$$

The per-period indirect utility for a citizen and a special interest can be obtained by substituting (3) and (4) into (1) and (2), respectively;

$$v_c = [l + r(t) - \tau]/\alpha_c + s - h(\eta, x),$$

$$v_s = [\pi(t) + \tau]/\alpha_s + s.$$

Thus, the per-period aggregate welfare for citizens can be written as

$$V_c = l + r(t) - \tau + \alpha_c [s - h(\eta, x)], \tag{5}$$

and that for special interests can be written as

$$V_s = \pi(t) + \tau + \alpha_s s. \tag{6}$$

Per-period aggregate social welfare is the sum of V_c and V_s.

$$V_a = \pi(t) + l + r(t) + s - \alpha_c h(\eta, x). \tag{7}$$

2.2.5 Politicians

There are two types of politicians in the economy: "pro-welfare" and "pro-industry". Both types of politician obtain positive utility only when in office and have a common discount factor δ. When in power, the pro-welfare politician's preference exactly coincides with the aggregate social welfare. Thus, from (7), the per-period utility for a pro-welfare politician

in office is represented by

$$v_w(t, \eta) = \pi(t) + l + r(t) + s - \alpha_c h(\eta, x). \tag{8}$$

Note that the pro-welfare politician's per-period utility does not depend on the amount of direct transfers τ. On the other hand, the pro-industry politician cares only about the welfare of the special interests when in power. Thus, from (6), the per-period utility for a pro-industry politician in office is represented by

$$v_p(t, \tau) = \pi(t) + \tau + \alpha_s s. \tag{9}$$

Note that the pro-industry politician's per-period utility does not depend on the parameter η in the environmental damage function.

2.2.6 Uncertainty

The economy is subject to two types of uncertainty. The first is pollution uncertainty. The citizen does not know the risk of environmental damage that the production of good x causes. In particular, the citizen does not know about the realization of the parameter η in the environmental damage function $h(\eta, x)$. The second type of uncertainty concerns the types of politicians. In particular, the citizen does not know the types of the politicians (both incumbent and challenger).

2.2.6.1 Pollution Uncertainty

As discussed in 2.2.2, environmental damages caused by the production of good x depend on the amount of production x and the unknown parameter η. The parameter η represents the risk of environmental damage. Assume, for simplicity, that with probability η each unit of production of x generates one unit of pollution, and that with probability $(1 - \eta)$ the

production of x does not generate pollution. That is,

$$h(\eta, x) = \begin{cases} x & \text{with probability } \eta, \\ 0 & \text{with probability } 1 - \eta. \end{cases}$$

Thus, η can be interpreted as the probability that the production of good x causes pollution. The expected environmental damage, then, becomes ηx. (Refer to the state in which the production of good x causes environmental damage to d and the state with no environmental damage to n.)

The pollution uncertainty concerns the realization of η. In particular, the realization of η is assumed to take one of two values, $\{\eta_H, \eta_L\}$, where $\eta_H > \eta_L$. An incumbent politician observes the realization of η prior to decisions, however, the citizen cannot.[13] Instead, the citizen receives signal σ. That is, while the citizen cannot observe the true value of η, he knows that with probability σ the state is η_H and with probability $(1 - \sigma)$ the state is η_L. Note that both states (whether η_H or η_L) can result in the same ex-post damages (either d or n). Therefore, it is not possible for the citizen to infer η from a realized environmental damage.

Although it has been assumed that governments have better information about pollution damage than citizens, in reality there is likely to be heterogeneity of information quality across citizens. Environmental NGOs, for example, may have very good information about environmental damage. However, in a world where polluters and NGOs are both trying to influence public opinion, the median voter will have difficulty in trying to decide what to believe. Hence it is reasonable to assume that the median voter is less well-informed than the government (which has paid experts at its disposal). For simplicity, the heterogeneity of information across citizens has not been modelled. Using a representative citizen model, with the representative citizen meant to capture the behavior of the median voter, it is therefore reasonable to assume that politicians have better information than voters.

[13] Thus, only the incumbent politician knows how likely the production of good x is to cause environmental damage. However, even the incumbent politician does not know whether the production of good x really causes environmental damage. He knows only the likelihood of environmental damage.

2.2.6.2 Politician Uncertainty

The second type of uncertainty concerns the types of politicians. In particular, the citizen does not know whether the incumbent politician is pro-welfare or pro-industry. Instead, at the beginning of period 1 the citizen receives signal $\rho \in (0,1)$ with regard to the politician's type. It represents the probability that the incumbent politician is pro-welfare. Also, the citizen does not know the challenger's type. At the time of election, the citizen receives a signal λ with regard to the challenger's type. It represents the probability that the challenger is pro-welfare. Assume that the signal λ is drawn from some smooth and increasing probability distribution F. Note that the incumbent politician knows ρ but does not know λ until the end of period 1.

2.2.7 The Games and the Equilibrium Definition

This two-period game has three players: the citizen, the incumbent politician, and the challenger. At the beginning of the game, nature chooses the incumbent's type, whether he is pro-welfare or pro-industry. The citizen cannot observe the incumbent type, but receives a signal of his type ρ. Nature then chooses the probability that the production of good x causes pollution $\eta \in \{\eta_H, \eta_L\}$. η can be observed only by the incumbent politician. The citizen knows only $\sigma = \Pr(\eta = \eta_H)$. Then, the incumbent politician announces the environmental policy t and the level of direct cash transfer to the special interests τ. The incumbent's choices (t, τ) and the realized pollution damages $h \in \{d, n\}$ can be observed by the citizen. Thus, the incumbent's 1st period record can be represented by (t, τ, h).

There is an election at the end of the period 1. Nature chooses whether the challenger is pro-welfare or pro-industry. The citizen cannot observe the challenger's type, but receives a signal of his type λ from the probability distribution F. Knowing λ and the incumbent's 1st period record (t, τ, h), the citizen decides whom to elect.[14] In the second period, the winner

[14] As mentioned at the beginning of this section, the citizens alone can determine the outcome of the election, while the special interests cannot. Focusing on the situation in which with no uncertainty the pro-welfare type is always elected, how can the pro-industry type be elected? If the special interests have rights to vote, the outcome of the election will depend on their relative fraction in the total population. In that sense, this study considers the case when the fraction of the citizens is large relative to the special interests.

of the election chooses the environmental policy and the direct transfers in that period. Then, the game ends. Figure 1 illustrates the timing of events.

The equilibrium concept employed is a perfect Bayesian equilibrium. It consists of a strategy for each type of incumbent, the strategy for each type of challenger, and the strategy and the beliefs of the citizen. The strategy for the incumbent is a rule that specifies (t, τ) for each type and η in the first period, and that in the second period if re-elected. The strategy for the challenger is a rule that specifies (t, τ) in the second period for each type and η if elected. The strategy for the citizen is a rule that specifies probability that he will re-elect the incumbent. The equilibrium conditions are: (1) the incumbent's strategy is optimal given the citizen's strategy and beliefs and the challenger's strategy; (2) the challenger's strategy is optimal; (3) the citizen's strategy is optimal given his own beliefs and the strategies for the incumbent and the challenger; (4) the citizen's beliefs are consistent with the incumbent's strategy in the sense that they are computed from Bayesian updating where possible.

2.3 Politician's and Citizen's Choices

This section solves the game described above and analyzes the equilibrium policy choices. The game can be solved by backward induction.

2.3.1 Politician's Choice in the Second Period

Suppose that the pro-welfare politician is in office in the second period. When $\eta = \eta_j$ $(j = H, L)$, the pro-welfare politician solves

$$\max_{t,\tau} v_w(t, \eta_j).$$

Given the pro-welfare politician's preference in (8), the solution to this problem can be shown to be

$$\hat{t}(\eta_j) = \alpha_c \eta_j, \ \hat{\tau} = 0,$$

which implies that the pro-welfare politician, who cares only about the aggregate social welfare, equates the pollution tax t with the expected marginal damage from pollution $\alpha_c \eta_j$ and chooses zero cash transfer.[15] That is, the pro-welfare politician in office in the second period always chooses the efficient Pigovian tax $\hat{t}(\eta_j)$ together with zero cash transfer $\hat{\tau} = 0$ and obtains the utility level of

$$\begin{aligned} v_w(\hat{t}(\eta_j), \eta_j) &= \pi(\hat{t}(\eta_j)) + l + r(\hat{t}(\eta_j)) + s - \alpha_c h(\eta, x(\hat{t}(\eta_j))), \\ &= \pi(\hat{t}(\eta_j)) + l + s + (\hat{t}(\eta_j) - \alpha_c \eta_j) x(\hat{t}(\eta_j)), \\ &= \pi(\hat{t}(\eta_j)) + l + s, \end{aligned}$$

when the state is η_j. Note that the last equality comes from $\hat{t}(\eta_j) = \alpha_c \eta_j$. Note also that the above expression represents the maximum level of utility that the society can achieve when η_j.

Next, suppose that the pro-industry politician is in power in the second period. The pro-industry politician solves

$$\max_{t,\tau} v_p(t, \tau).$$

As a benchmark case, suppose that no direct transfers are available. In this case, the pro-industry politician faces the problem,

$$\max_{t} v_p(t, 0).$$

Obviously, given the pro-industry politician's preference in (9), the solution to this problem is $t = 0$. Therefore, when the pro-industry politician cannot access direct transfers, he will always choose a too low (zero) pollution tax to help the special interests.

Now consider both instruments are available. In this case, it can be shown that the pro-industry politician will no longer have an incentive to use a weak environmental policy to redistribute income to the special interests.

Lemma 1 : When direct transfers are available, the pro-industry politician in office in the

[15] Note again that τ has no effect on the pro-welfare politician's per-period utility.

second period chooses the efficient Pigovian tax combined with positive direct transfers.

Proof: Given the preference in (9), the pro-industry politician in office in the second period will always choose the maximum possible amount of direct transfers, which can be written, when η_j, as

$$\tau(\eta_j) = l + r(t) + \alpha_c \left[s - h(\eta_j, x(t)) \right],$$

for a given pollution tax t. Substituting the above into the pro-industry politician's second period utility to obtain

$$\begin{aligned} v_p(t, \hat{\tau}(\eta_j)) &= \pi(t) + \tau(\eta_j) + \alpha_s s, \\ &= \pi(t) + l + r(t) + s - \alpha_c h(\eta_j, x(t)). \end{aligned}$$

The final expression obviously represents the aggregate social welfare and this can be maximized by choosing the efficient Pigovian tax $\hat{t}(\eta_j)$. Q.E.D.

The lemma 1 states that the pro-industry politician, once allowed to use direct transfers, will use them to redistribute income to special interests and a pollution tax to internalize environmental externalities.[16] The reason is that choosing an inefficient environmental policy will reduce the amount of resources available for income transfer. Now define

$$\hat{\tau}(\eta_j) = l + r(\hat{t}(\eta_j)) + \alpha_c \left[s - h(\eta_j, x(\hat{t}(\eta_j))) \right].$$

Then, by lemma 1, the pro-industry politician in office in the second period chooses $\hat{\tau}(\eta_j)$ together with the efficient Pigovian tax $\hat{t}(\eta_j)$ and obtains the utility level of

$$\begin{aligned} v_p(\hat{t}(\eta_j), \hat{\tau}(\eta_j)) &= \pi(\hat{t}(\eta_j)) + \hat{\tau}(\eta_j) + \alpha_s s, \\ &= \pi(\hat{t}(\eta_j)) + l + s, \end{aligned}$$

when the state is η_j.

Note that the maximum levels of utilities are the same for both types of politicians. Thus,

[16] Thus, the principles of targeting can be applied here.

from now on, this is denoted as

$$\begin{aligned}\hat{v}(\eta_j) &= v_w(\hat{t}(\eta_j), \eta_j) \\ &= v_p(\hat{t}(\eta_j), \hat{\tau}(\eta_j))\end{aligned}$$

2.3.2 Citizen's Choice

The citizen will be better off if a pro-welfare politician is in power and hence elect the politician who he believes is pro-welfare. Now define $\hat{\rho}(t, \tau, h)$ as the citizen's estimate of the probability that the incumbent politician is pro-welfare given the incumbent's first period record (t, τ, h). Then, the citizen will re-elect the incumbent if and only if

$$\hat{\rho}(t, \tau, h) > \lambda.$$

Since the challenger's initial reputation λ is assumed to be drawn from the probability distribution F, the probability that the incumbent politician will be re-elected when his first period record is (t, τ, h) can be written as $F(\hat{\rho}(t, \tau, h))$.

2.3.3 Incumbent's Choice in the First Period

2.3.3.1 Pro-Welfare Incumbent

As discussed above, if re-elected, the pro-welfare incumbent will choose $(\hat{t}(\eta_j), 0)$ and obtain the second period utility $\hat{v}(\eta_j)$ when $\eta = \eta_j$ $(j = H, L)$. Thus, if the pro-welfare incumbent does not select a positive direct transfer in the first period $(\tau = 0)$, his expected discounted utility can be written as

$$v_w(t, \eta_j) + \delta[\eta_j F(\hat{\rho}(t, 0, d)) + (1 - \eta_j) F(\hat{\rho}(t, 0, n))]\hat{v}(\eta_j),$$

for a given first period pollution tax t. On the other hand, if he chooses a positive direct transfer ($\tau > 0$), his expected discounted utility can be written as

$$v_w(t, \eta_j) + \delta[\eta_j F(\hat{\rho}(t, \tau, d)) + (1 - \eta_j) F(\hat{\rho}(t, \tau, n))]\hat{v}(\eta_j),$$

for a given first period t. Thus, comparing the above two expressions, one can find that the decision for direct transfers (whether $\tau = 0$ or $\tau > 0$) affects only the probability of re-election through the citizen's beliefs. For any first period record that arises with positive probability, these beliefs must be calculated from the incumbent strategy by Bayes' rule. On the other hand, the definition of the perfect Bayesian equilibrium does not pin down the citizen's beliefs off the equilibrium path. Indeed, depending on out-of-equilibrium beliefs, various types of equilibria are possible.[17] However, examining every possible out-of-equilibrium belief would just complicate the analysis. Thus, this study assumes, as in Coate and Morris (1995), that the citizen's beliefs satisfy a simple monotonic property that $\hat{\rho}(t, \tau, h) \geq \hat{\rho}(t, \tau', h)$ for any (t, τ, h) and (t, τ', h) such that $\tau' > \tau$. This implies that the first period record with a smaller amount of transfer can give more optimistic beliefs about the incumbent. If the citizen has these monotonic beliefs, the following lemma can be obtained.

Lemma 2 (Coate and Morris (1995)) : Under monotonic beliefs, the pro-welfare incumbent never chooses $\tau > 0$ in the first period.

Lemma 2 states that under the monotonic beliefs the pro-welfare incumbent has no incentive to make positive transfers in the first period. Doing this will only result in decreasing his probability of winning elections.

Finally, define $t_w(\eta_j)$ as the first period pollution tax that maximizes the pro-welfare incumbent's expected discounted utility. That is, the pro-welfare incumbent's optimal choice is $(t_w(\eta_H), 0)$ when η_H and $(t_w(\eta_L), 0)$ when η_L. Notice that if the pro-welfare incumbent does not need to worry about his reputation, he will choose the first period pollution tax

[17] For example, it is possible to have equilibrium where all incumbent types always choose positive direct transfers to the special interest. This equilibrium is supported by the somewhat strange out-of-equilibrium belief that any incumbent choosing zero transfer must be pro-industry.

that maximizes only his first period utility, i.e., the efficient Pigovian pollution tax $\hat{t}(\eta)$. However, if re-election is his concern, the pro-welfare incumbent will choose t, taking into consideration his probability of winning the election as well as his first period utility. Thus, it is not necessarily the case that $t_w(\eta) = \hat{t}(\eta)$.

2.3.3.2 Pro-Industry Incumbent

If the pro-industry incumbent is in office in the second period, he will choose $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ and obtain the second period utility $\hat{v}(\eta_j)$ when $\eta = \eta_j$ $(j = H, L)$. Thus, if the pro-industry incumbent does not select a positive direct transfer in the first period ($\tau = 0$), his expected discounted utility can be written as

$$v_p(t, 0) + \delta[\eta_j F(\hat{\rho}(t, 0, d)) + (1 - \eta_j) F(\hat{\rho}(t, 0, n))]\hat{v}(\eta_j),$$

for a given first period pollution tax t. On the other hand, if he chooses a positive direct transfer ($\tau > 0$), then his expected discounted utility can be written as

$$v_p(t, \tau) + \delta[\eta_j F(\hat{\rho}(t, \tau, d)) + (1 - \eta_j) F(\hat{\rho}(t, \tau, n))]\hat{v}(\eta_j),$$

for a given first period t. Now recall lemma 2. Lemma 2 claims that the pro-welfare incumbent never chooses a positive direct transfer in the first period. In particular, the pro-welfare incumbent selects $(t_w(\eta_j), 0)$ when η_j $(j = H, L)$. Therefore, if the citizen observes the incumbent politician choosing strategy other than $(t_w(\eta_j), 0)$, then he will conclude that the incumbent is pro-industry and vote him out of office. This implies that if the pro-industry incumbent behaves as above, then he does so to maximize only his first period utility. As discussed above, once election is of no concern,[18] the pro-industry politician will use direct transfers to redistribute income to the special interests and use pollution tax to internalize environmental externalities. That is, if the pro-industry incumbent decides not to mimic the pro-welfare incumbent's behavior, he will choose $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ when η_j. Thus, the following

[18] In the second period, a politician, whether he is pro-welfare or pro-industry, has no electoral concern.

lemma concerning the pro-industry incumbent's first period choice can be obtained.

Lemma 3 : Under the monotonic beliefs, the pro-industry incumbent's first period choices are either $(t_w(\eta_H), 0)$, $(t_w(\eta_L), 0)$, or $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ when η_j, $j = H, L$.

Lemma 3 states that the pro-industry incumbent's first period choices are either to mimic the behaviors of the pro-welfare incumbent or to choose the efficient Pigovian tax combined with positive direct transfers so as to maximize his first period utility. Which action he will take depends on the citizen's beliefs. The next section addresses this issue.

2.4 Equilibrium Analysis

2.4.1 Pooling Equilibrium

As discussed in section 2.2, in this economy voters are subject to two types of uncertainties. One is uncertainty about politicians; the voters cannot observe politician's types to ascertain whether he is pro-welfare or pro-industry. The other is uncertainty about pollution; the voters cannot observe how risky the environmental damages that production of a good x causes. Thus, in this model, there is an obvious incentive for a pro-industry incumbent to understate environmental damages and hence implement a too weak environmental regulation that benefits special interests. In fact, as lemma 3 indicates, while the pro-industry incumbent has an incentive to announce the policy that fully reveals his type, he also has an incentive to hide his type by announcing the tax rate that the pro-welfare incumbent would set in some states of the world.

While there are many types of pooling equilibria, this section focuses on one interesting case; the pro-industry incumbent chooses the tax rate that the pro-welfare incumbent does when the risk of environmental damage is low. That is, the pro-industry incumbent announces that the risk of environmental damage is low (even when it is high) and implements a too low pollution tax that benefits the special interests. An equilibrium of this type exists for some values of incumbent's initial reputation ρ. In particular, in equilibrium the pro-welfare incumbent always implements the efficient Pigovian tax, while the pro-industry

incumbent always selects the lower of the two. That is, $\hat{t}(\eta_L)$. Before characterizing such an equilibrium, assume the following.

Assumption 1 : Election matters for a pro-industry incumbent only to the extent that he can choose the weaker environmental policy ($\hat{t}(\eta_L)$) rather than stricter one ($\hat{t}(\eta_H)$). That is, for $j = H, L$

$$\hat{v}(\eta_j) - v_p(\hat{t}(\eta_L), 0) < \delta\hat{v}(\eta_j) < \hat{v}(\eta_j) - v_p(\hat{t}(\eta_H), 0).$$

The above assumption implies that for a pro-industry politician utility loss from not implementing his full information policy $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ relative to $(\hat{t}(\eta_L), 0)$ is always less than, but that relative to $(\hat{t}(\eta_H), 0)$ is always greater than the discounted value of his maximum utility in the second period. Under assumption 1, the following result can be obtained.

Proposition 1 : There is an equilibrium in which the pro-industry incumbent makes inefficient transfers to special interests when the risk of environmental damage is high by always choosing $(\hat{t}(\eta_L), 0)$ while the pro-welfare incumbent always implements the efficient Pigovian taxes, if $\rho > \rho^* \in (0, 1)$.

Proof: See Appendix A.

Proposition 1 shows that there is an equilibrium in which the pro-industry politician uses the environmental policy as an instrument for income redistribution, and that this equilibrium can be sustained if the incumbent's initial reputation is above some critical level. The intuition is as follows: In the equilibrium, the pro-industry incumbent knows that if he makes direct transfers and/or sets pollution taxes other than the Pigovian ones, his type will be revealed and he will be voted out of office. An alternative way of transferring income to the special interests is to set, when η_H, the tax rate that the pro-welfare incumbent would choose when η_L. The reputational penalty for doing this will be less severe than a penalty for making direct transfers and/or setting other tax rates. Although the citizen knows these incentives for the pro-industry incumbent, he cannot perfectly infer from this record that

an incumbent is pro-industry. The reason is that the pro-welfare incumbent can select this policy in some states of the world and the citizen cannot observe the realization of η.

Figure 2 illustrates this situation. The curve passing through the point a represents the pro-welfare incumbent's lifetime utility as a function of t when the initial reputation is $\rho > \rho^*$ and the state is η_L. This function attains its maximum at point a when choosing $\hat{t}(\eta_L)$. At this point, the pro-welfare incumbent's utility is higher than at point d where he could attain by choosing $\hat{t}(\eta_H)$. On the other hand, the curve passing through the point b (c) represents the pro-industry incumbent's lifetime utility if mimicking the pro-welfare incumbent's behavior when the initial reputation is ρ and the state is η_L (η_H). As can be seen, the pro-industry incumbent's utility at point b (c) is higher than that when choosing full information policy $\hat{v}(\eta_L)$ ($\hat{v}(\eta_H)$).

For an application of the model, note that the pooling equilibrium described above can be interpreted as a characterization of the government's behavior of not adopting stringent environmental regulations, e.g., the U.S. regulations towards fisheries and groundwater. They (pro-industry governments) claim that the current environmental risk is not so serious (i.e., the state is η_L not η_H) and that the introduction of tougher environmental regulation ($\hat{t}(\eta_H)$) is too costly to have a negative impact on the economy. By adopting insufficient environmental policy ($\hat{t}(\eta_L)$), those governments can protect industry profits and stay in office.

Notice that the above result can be closely related to the one by Coate and Morris (1995). They examined the possibility that a public project can be used as an inefficient instrument for transferring income in a model in which politicians face a binary decision problem as to whether to undertake the project together with the direct transfers. They characterize the pooling equilibrium in which a bad politician undertakes an unsuccessful project for redistribution purposes. While the present model, unlike Coate and Morris (1995), has many other pooling equilibria,[19] the pooling equilibrium characterized in proposition 1 can be interpreted as one application of Coate and Morris (1995) to the environmental policy to

[19]In fact, the pooling equilibrium in the present model can be sustained not only for the Pigovian tax but also for other (and possibly close) tax rates. This is not possible for Coate and Morris (1995).

explain why it can be used as an inefficient instrument for income redistributions.

2.4.2 Separating Equilibrium

In contrast to the previous discussion, this section examines the opposite side of a government's behavior. That is, it questions why governments sometimes adopt policies that seem too stringent. It will be shown that there is an equilibrium in which the pro-welfare incumbent announces an inefficient environmental policy as a way to separate himself from the pro-industry politician and hence win election.

In particular, this section seeks to find a separating equilibrium in which the pro-welfare incumbent announces a too stringent environmental policy when the risk of environmental damage is low but still implements the efficient environmental policy when it is high. In general, in a separating equilibrium, the incumbent's choice of environmental policy fully reveals his type. Therefore, considering lemma 3, it is obvious that in any separating equilibrium the pro-industry incumbent chooses the environmental policy that fully reveals his type; that is, he chooses $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ when η_j $(j = H, L)$.

In order to have a separating equilibrium, two conditions are needed. The first is that the pro-industry incumbent should not benefit by mimicking the pro-welfare incumbent. Suppose that, as in the pooling equilibrium, the citizen's out of equilibrium beliefs are given by $\hat{\rho}(t, \tau, h) = 0 \ \forall \ (t, \tau) \neq (t_g(\eta_H), 0), (t_g(\eta_L), 0)$ and $h \in \{d, n\}$. Given these, the pro-industry incumbent will not benefit by mimicking the pro-welfare incumbent if $t_w(\eta_j) \in A$, where $A = A_H \cap A_L$, and for $j = H, L$,

$$A_j = \left\{ t \mid v_p(t, 0) + \delta \hat{v}(\eta_j) \leq \hat{v}(\eta_j) \right\}.$$

Let $\bar{t}_{pj}$ (> 0) denote the pollution tax rate that satisfies the following.

$$v_p(t, 0) + \delta \hat{v}(\eta_j) = \hat{v}(\eta_j).$$

Then, the set A_j consists of all the tax rates not less than $\bar{t}_{pj}$. A pro-industry incumbent

would be willing to choose any tax rate lower than this together with zero transfer ($\tau = 0$) if by doing so, he could fool the citizen into believing he is pro-welfare. Whether $\hat{t}(\eta_j)$ falls into this set is critical in discussing the pro-welfare incumbent's behavior. However, recall assumption 1 in the preceding section. Under assumption 1,

$$v_p(\hat{t}(\eta_H), 0) + \delta\hat{v}(\eta_j) < \hat{v}(\eta_j) < v_p(\hat{t}(\eta_L), 0) + \delta\hat{v}(\eta_j).$$

for $j = H, L$. Therefore, $\hat{t}(\eta_H) \in A$, but $\hat{t}(\eta_L) \notin A$. That is, the pro-industry incumbent always has an incentive to select $(\hat{t}(\eta_L), 0)$ if this gives him re-election with probability one, while he has no incentive to choose $(\hat{t}(\eta_H), 0)$ even if $\hat{\rho}(\cdot, \cdot, \cdot) = 1$. This implies that the pro-welfare incumbent can separate himself by choosing the Pigovian tax when the risk of environmental damage is high but he cannot when it is low. How does the pro-welfare incumbent choose the environmental policy when η_L?

The second condition for a separating equilibrium is that the pro-welfare incumbent should benefit by deviating from the Pigovian tax $\hat{t}(\eta_L)$ when η_L. The pro-welfare incumbent would be willing to choose $t_w(\eta_L) \neq \hat{t}(\eta_L)$, if $t_w(\eta_L) \in B_L$, where,

$$B_L = \{t \mid v_w(t, \eta_L) + \delta\hat{v}(\eta_L) \geq \hat{v}(\eta_L)\}.$$

Let $\underline{t}_{wL}$ and $\bar{t}_{wL}$ denote the lower and the higher values of t such that the following holds.

$$v_w(t, \eta_L) + \delta\hat{v}(\eta_L) = \hat{v}(\eta_L).$$

Then, the set B_L consists of all the tax rates inside the interval $\left[\underline{t}_{wL}, \bar{t}_{wL}\right]$. Thus, the set $B_L \cap A$ contains all the possible separating equilibrium strategies when η_L for a pro-welfare incumbent.

Before characterizing the separating equilibrium, assume the following.

Assumption 2 : A pro-industry incumbent's incentive for redistribution is sufficiently

higher so that the following holds.

$$\hat{v}(\eta_H) - v_p(\bar{t}_{gL}, 0) > \delta\hat{v}(\eta_H).$$

Assumption 2 implies that the pro-industry incumbent's incentive to protect the special interests is so strong that choosing the pollution tax rate $\bar{t}_{wL}$ is too costly for him. Under assumptions 1 and 2, the following result can be obtained.

Proposition 2 : There is an equilibrium in which the pro-welfare incumbent implements a too stringent environmental policy to separate from the pro-industry incumbent when the risk of environmental damage is low by choosing $(t_w(\eta_L), 0)$, where $t_w(\eta_L) \in B_L \cap A$, and $t_w(\eta_L) > \hat{t}(\eta_L)$, while the pro-industry incumbent always chooses the full information policy.

Proof: Given equilibrium strategies for each type of incumbent, the set of beliefs along the equilibrium paths are given by

$$\hat{\rho}(\hat{t}(\eta_H), 0, h) = 1,$$
$$\hat{\rho}(t_w(\eta_L), 0, h) = 1,$$
$$\hat{\rho}(\hat{t}(\eta_H), \hat{\tau}(\eta_H), h) = 0,$$
$$\hat{\rho}(\hat{t}(\eta_L), \hat{\tau}(\eta_L), h) = 0,$$

for $h \in (d, n)$.

Assumption 1 implies that $\hat{t}(\eta_L) \in \left(0, \bar{t}_{pL}\right) \cap \left(0, \bar{t}_{pH}\right)$. However, given the pro-industry politician's preference, $\bar{t}_{pL} < \bar{t}_{pH}$. Therefore, $\hat{t}(\eta_L) \in \left(0, \bar{t}_{pL}\right)$, and the set A consists of all the tax rates not less than $\bar{t}_{pH}$. Also, note that $\hat{t}(\eta_L) \in \left[\underline{t}_{wL}, \bar{t}_{wL}\right]$. Thus, by assumption 2, the set $B_L \cap A$ is not empty and consists of all the tax rates $t \in \left[\bar{t}_{pH}, \bar{t}_{wL}\right]$. Note that for any t within this interval $t > \hat{t}(\eta_L)$.

The proof shall be completed by showing that for a pollution tax rate $t_w(\eta_L) \in \left[\bar{t}_{pH}, \bar{t}_{wL}\right]$ the pro-welfare incumbent selects $(\hat{t}(\eta_H), 0)$ when η_H and selects $(t_w(\eta_L), 0)$ when η_L, and the

pro-industry incumbent chooses $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ when η_j $(j = H, L)$ given out-of-equilibrium beliefs $\hat{\rho}(t, \tau, h) = 0 \; \forall \; (t, \tau) \neq (\hat{t}(\eta_H), 0)$ and $(t_w(\eta_L), 0)$, and $h \in \{d, n\}$.

Consider, first, the pro-welfare incumbent's behavior. When η_H, the pro-welfare incumbent always selects $(\hat{t}(\eta_H), 0)$ since this is his one period optimum and gives him re-election with probability one. When η_L, the pro-welfare incumbent chooses $(t_w(\eta_L), 0)$ rather than choosing $(\hat{t}(\eta_L), 0)$ since $t_w(\eta_L) \in B_L$, that is,

$$v_w(t_w(\eta_L), \eta_L) + \delta\hat{v}(\eta_L) \geq \hat{v}(\eta_L).$$

Next, consider the pro-industry incumbent's behavior. When η_j, the pro-industry incumbent chooses $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ rather than $(t_w(\eta_L), 0)$ since $t_w(\eta_L) \in A$, that is,

$$v_p(t_w(\eta_L), 0) + \delta\hat{v}(\eta_j) \leq \hat{v}(\eta_j),$$

for $j = H, L$. Q.E.D.

Proposition 2 demonstrates the existence of an equilibrium in which a pro-welfare incumbent implements the inefficient environmental policy to separate himself from the pro-industry incumbent. The inefficiency can be characterized as too strict in the sense that the chosen pollution tax exceeds its efficient level, that is, $t_w(\eta_L) > \hat{t}(\eta_L)$. The intuition is as follows: In the equilibrium, the pro-welfare incumbent knows that if he chooses the efficient Pigovian tax $\hat{t}(\eta_L)$ when η_L, his type will not be revealed since the pro-industry incumbent now has an incentive to choose this tax rate. In order to be successfully re-elected, the pro-welfare incumbent will choose the tax rate that is different from the Pigovian tax rate and is not with the pro-industry incumbent's interest. Choosing this tax rate gives him re-election with probability one and hence higher lifetime utility though it decreases the first period aggregate social welfare.

This establishes that the pro-welfare incumbent has an incentive to implement inefficiently strict environmental policy when the risk of environmental damage is low $(\eta = \eta_L)$. Now, the question is how he should select the environmental policy from the possible candi-

date $[\bar{t}_{pH}, \bar{t}_{wL}]$.

In demonstrating the existence of the separating equilibrium, the citizen's out of equilibrium beliefs were assumed to be given by $\hat{\rho}(t, 0, h) = 1$ for $t = t_w(\eta_L), \hat{t}(\eta_H)$, and $h \in \{d, n\}$. However, this assumption seems rather restrictive as the pro-industry incumbent will have no incentive to choose any tax rate $t \in B_L \cap A$. Therefore, much more plausible restrictions on the citizen's belief are $\hat{\rho}(t, 0, h) = 1 \; \forall \; t \in B_L \cap A$, $\hat{t}(\eta_H)$ and $h \in \{d, n\}$. Once a citizen's beliefs are given as above, the pro-welfare incumbent can now select any separating environmental policy that is most favorable to him, that is, the least-distorting one. According to Rogoff (1990), this separating environmental policy $t_w(\eta_L)$ can be characterized by the solution to the following optimization problem,

$$\max_t v_w(t, \eta_L),$$

$$s.t. \; t \in A.$$

The following proposition with regard to the pro-welfare incumbent's choice can be obtained.

Proposition 3 : In the least distorting separating equilibrium, the pro-welfare incumbent chooses $\bar{t}_{pH}$ $\left(> \hat{t}(\eta_L)\right)$ when η_L; that is, the pro-welfare incumbent chooses a too strict, but least-distorting, environmental policy to separate himself from the pro-industry incumbent.

The above proposition shows that if the pro-welfare incumbent can freely choose any separating tax rate from the interval $[\bar{t}_{pH}, \bar{t}_{wL}]$, he will choose the one that is closest to its efficient level, that is, the least-distorting one. Thus, the pro-welfare politician chooses $\bar{t}_{pH}$ when η_L to separate himself from the pro-industry politician and hence win the election.[20]

Figure 3 illustrates this situation. The curve passing through the point e represents the pro-welfare incumbent's lifetime utility when η_L as a function of t in any separating equilibrium. As in the pooling equilibrium, this function attains its maximum when choosing

[20]Note that the least distorting separating equilibrium described above also satisfies the criterion for equilibrium selection by Cho and Kreps (1987). Moreover, it can be shown that among any separating strategy $(t, 0)$ such that $t \in B_L \cap A$ this equilibrium is the only equilibrium that satisfies the criterion.

$\hat{t}(\eta_L)$. However, this tax rate cannot be sustained as a separating equilibrium, since by mimicking the pro-welfare incumbent's behavior the pro-industry incumbent could attain higher utility at point f (g) when η_L (η_H) than that when choosing full information policy. Therefore, the pro-welfare incumbent chooses the tax rate that does not benefit the pro-industry incumbent ($t > \bar{t}_{pH}$), but benefits himself ($t \in [\underline{t}_{wL}, \bar{t}_{wL}]$), that is, $t \in [\bar{t}_{pH}, \bar{t}_{wL}]$. Within this interval, the pro-welfare incumbent chooses the tax rate that gives him the highest lifetime utility, $t = \bar{t}_{pH}$. As can be seen, the pro-welfare incumbent's utility at this point e is higher than any other point within this interval, and the pro-industry incumbent has no incentive to choose this tax rate.

For another application of the model, note that the separating equilibrium described above can be interpreted as a characterization of the government's behavior of implementing tougher environmental regulations, e.g., mandatory vehicle I/M and the recycling programs in North America. They (pro-welfare governments) claim that the current environmental risk is so serious (i.e., the state is η_H) that the immediate implementation of stricter environmental policy ($\bar{t}_{pH}$) is needed. Despite recognizing its over strictness ($\bar{t}_{pH} > \hat{t}(\eta_L)$), those governments adopt such policies and hence stay in office.

2.4.3 Selection of Equilibrium

The preceding two subsections concern the existence of two different types of equilibria. In particular, section 2.4.1 focuses on the pooling equilibrium in which the pro-industry politician mimics the pro-welfare incumbent's behavior by choosing a too weak environmental policy instead of direct income transfers as a way to transfer income to the special interests. On the other hand, section 2.4.2 characterizes the separating equilibrium in which the pro-welfare politician who recognizes the pro-industry politician's incentives implements a too strong environmental policy to separate himself from the pro-industry politician. The natural question that arises is which equilibrium is more plausible.

According to the criterion for equilibrium selection proposed by Cho and Kreps (1987), a pooling equilibrium $(\hat{t}(\eta_L), 0)$ with $\hat{\rho}(t, \tau, h) = 0$, $\forall (t, \tau) \neq (\hat{t}(\eta_j), 0)$, $j = H, L$, and $h \in$

$\{d, n\}$, is unintuitive if there is a strategy $(t, 0)$ such that

1. the pro-welfare incumbent wants to deviate to $(t, 0)$ if $\hat{\rho}(t, 0, h) = 1$, $h \in \{d, n\}$, that is,

$$v_w(t, \eta_L) + \delta\hat{v}(\eta_L) > [1 + \delta g(\eta_L, \rho)]\,\hat{v}(\eta_L),$$

and

2. the pro-industry incumbent does not want to deviate to $(t, 0)$ even if $\hat{\rho}(t, 0, h) = 1$, $h \in \{d, n\}$, that is, for $j = H, L$,

$$v_p(t, 0) + \delta\hat{v}(\eta_j) < v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_j, \rho)\hat{v}(\eta_j).$$

Note that the function g represents the probability of re-election in the pooling equilibrium when the incumbent's initial reputation is ρ and the state is η_i.[21] The particular question that is examined here is whether the pooling equilibrium characterized in section 2.4.1 can be dominated by the least-distorting separating equilibrium in section 2.4.2.

First, consider the pro-industry incumbent's incentives. In the pooling equilibrium,

$$v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_j, \rho)\hat{v}(\eta_j) \geq \hat{v}(\eta_j),$$

for $j = H, L$. On the other hand, in the least-distorting separating equilibrium,

$$\hat{v}(\eta_j) \geq v_p(\bar{t}_{pH}, 0) + \delta\hat{v}(\eta_j),$$

for $j = H, L$. Combining these gives

$$v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_j, \rho)\hat{v}(\eta_j) \geq v_p(\bar{t}_{pH}, 0) + \delta\hat{v}(\eta_j),$$

for $j = H, L$, indicating that the pro-industry incumbent has no incentive to deviate to the least-distorting separating strategy $(\bar{t}_{pH}, 0)$.

[21] See Appendix A for more discussion and the properties of g.

Next, consider the pro-welfare incumbent's incentives. In the pooling equilibrium, the pro-welfare incumbent obtains

$$[1 + \delta g(\eta_L, \rho)]\, \hat{v}(\eta_L),$$

while in the least-distorting separating equilibrium, he obtains

$$v_w(\bar{t}_{pH}, \eta_L) + \delta \hat{v}(\eta_L).$$

Thus, the pro-welfare incumbent wants to deviate to the least-distorting separating strategy $(\bar{t}_{pH}, 0)$ if

$$v_w(\bar{t}_{pH}, \eta_L) + \delta \hat{v}(\eta_L) \geq [1 + \delta g(\eta_L, \rho)]\, \hat{v}(\eta_L). \tag{10}$$

If the incumbent's initial reputation ρ is not so large that the probability of re-election in the pooling equilibrium is sufficiently small, then it is possible that the above inequality holds, indicating that the pooling equilibrium $(\hat{t}(\eta_L), 0)$ is unintuitive. The following proposition summarizes the result.

Proposition 4 : Suppose that the incumbent's initial reputation ρ is sufficiently small so that the following holds.

$$v_w(\bar{t}_{pH}, \eta_L) + \delta \hat{v}(\eta_L) \geq [1 + \delta g(\eta_L, \rho)]\, \hat{v}(\eta_L).$$

Then, the pooling equilibrium $(\hat{t}(\eta_L), 0)$ with $\hat{\rho}(t, \tau, h) = 0$ for $\forall (t, \tau) \neq (\hat{t}(\eta_j), 0)$, $j = H, L$, and $h \in \{d, n\}$, is unintuitive. That is, it is dominated by the least-distorting separating equilibrium.

As described above, the pro-industry incumbent never has an incentive to deviate to the least-distorting separating strategy. Whether the pro-welfare incumbent wants to deviate depends on the incumbent's initial reputation ρ. If ρ is sufficiently small so that it satisfies (10), then the pro-welfare incumbent finds it optimal to deviate to the least-distorting separating strategy. The reason is that the benefit from the pooling now becomes smaller as the lower ρ makes winning the election more difficult.

Figure 4 illustrates this situation. Point a in the figure indicates the pro-welfare incumbent's choice in the pooling equilibrium, while point e indicates that in the least-distorting separating equilibrium. If the incumbent's initial reputation ρ is sufficiently small, as described in the figure, the utility level at point e will be higher than that at point a, indicating that the pro-welfare incumbent would be willing to deviate from a to e. On the other hand, the points b and c indicate the pro-industry incumbent's choice in the pooling equilibrium when η_L and η_H, respectively. As described in the figure, the initial reputation allows for the existence of the pooling equilibrium so that the utility at points b and c will be higher than those when choosing the full information policies. Therefore, the pro-industry incumbent will have no incentive to deviate to the least-distorting separating equilibrium, as doing this will give him at best the utility that can be achieved when choosing the full information policies.

According to the propositions $1-4$, it is possible to categorize the incumbent's initial reputation ρ into the following three cases.

1. ρ is sufficiently large. In this case, both types of equilibria can exist and it is not possible to eliminate the pooling equilibrium based on the above criterion.

2. ρ is sufficiently small. In this case, the pooling equilibrium cannot be sustained and the least-distorting separating equilibrium is the most plausible equilibrium.

3. Intermediate ρ. In this case, both types of equilibria can still exist, but the pooling equilibrium can be dominated by the least-distorting separating equilibrium based on the above criterion.

Consider case 1 in which the incumbent's initial reputation is sufficiently large. In this case, the benefit from pooling is higher because of higher probability of winning the election. Thus, the pooling equilibrium is possible. On the other hand, by construction, in the separating equilibrium, for any $\rho \in (0,1)$, each incumbent type chooses his own separating strategy. Thus, the separating equilibrium is possible, too. For sufficiently higher ρ, expected second period utility in the pooling equilibrium becomes higher and close to that

in the separating equilibrium. The pro-welfare incumbent finds it optimal to stay in the pooling equilibrium and choose the efficient environmental policy rather than to deviate to the separating equilibrium and choose too stringent environmental policy that reduces his first period utility.

If, as in case 2, the incumbent's initial reputation is sufficiently small, expected second period utility becomes too small and hence the pooling equilibrium can not be sustained. On the other hand, the separating equilibrium is possible for any $\rho \in (0, 1)$ by the same reason explained above. Thus, the least distorting separating equilibrium is the only equilibrium that satisfies the intuitive criterion.

Finally, if, as in case 3, the incumbent's initial reputation is large enough to have the pooling equilibrium but not enough to give a sufficiently higher probability of winning the election, the pro-welfare incumbent finds it optimal to deviate from the pooling to the separating equilibrium and enjoy higher probability of re-election and hence higher second period utility at the expense of the first period utility. Again, as in case 2, the least distorting separating equilibrium is the only equilibrium that satisfies the intuitive criterion.

2.5 Concluding Remarks

This essay investigated why differences emerge among governments in the environmental regulations they choose. In particular, it explained why some governments choose environmental regulations that are too weak while others select overly strict environmental regulations by using a political economy framework. It examined how environmental policy can be used as a way to transfer resources to special interests in the presence of a more efficient instrument, and how it can be used even by a government who has no incentive to redistribute income.

The political economy model was used, in which voters are uncertain of the types of politicians and the risk of environmental damage. These two types of uncertainty make the weak environmental regulations an indirect way to transfer resources to the special interests at the expense of aggregate social welfare. First, there was a pooling equilibrium in which a pro-industry politician mimics the pro-welfare incumbent's behavior by choosing a too weak

environmental policy instead of direct income transfers as a way to transfer income to the special interests. That is, the pro-industry politician sometimes prefers to use inefficient methods of transfers even if more efficient instruments are available. The intuition is that politicians care about their reputations, and hence the pro-industry politician sometimes wants to maintain his good reputation. Then, there was also a separating equilibrium in which a pro-welfare politician, recognizing the pro-industry politician's incentives, implements too strict environmental policy to separate himself from the pro-industry politician. That is, despite its objective to maximize social welfare, the pro-welfare politician sometimes prefers to choose an inefficient environmental policy only for electoral purpose, even if doing so reduces the social welfare. Finally, it was demonstrated that if the incumbent's initial reputation is sufficiently weak, then the former equilibrium will be dominated by the latter. That is, we are more likely to see the separating equilibrium in which the pro-welfare incumbent chooses a too strict environmental policy to separate from the pro-industry incumbent.

Those two types of equilibria can be used to describe two opposite sides of a government's behavior. The pooling equilibrium describes the behavior of governments not adopting stricter environmental regulations, e.g., the U.S. policies towards fisheries and groundwater. Claiming that the environmental risk is not so serious, they can adopt insufficient environmental policy to protect industry profits. On the other hand, the separating equilibrium describes the behavior of governments implementing tougher environmental regulations, e.g., mandatory vehicle I/M and the recycling programs in North America. Claiming that the environmental risk is so serious, those governments, despite recognizing its over-strictness, adopt such policies to stay in office.

This essay considered the case of a single pollutant. Depending on government type, the model predicts that pollution regulation may be too stringent or too weak. More realistically, a given government regulates many types of pollution, with some pollutants regulated more stringently than others. The model could be extended to consider the case of multiple pollutants within the same country. Industry- and pollutant-specific factors, such as industry size, abilities to establish links to the government, and the visibility of the pollutant would be expected to affect the lobbying activity of polluters and the decision of the incumbent

politician regarding the stringency of regulation. Hence it is expected that an extension of the model could explain why some pollutants within a country may be over-regulated, while others are under-regulated.

This essay also focused entirely on the single country case. However, one important aspect in discussing the recent environmental problems is their global implications. Thus, the natural question that arises is how one country's decision on environmental policy will have an impact on the political economic choice of environmental policy in another country. In a multi-country world, there can be informational spillovers so that the home government's choice contains some signals about the foreign government's type and hence might politically affect a foreign government's behavior.

The model in this essay predicts that inefficient environmental policies (whether they are too stringent or too weak) may occur during the first term in office for an incumbent government that can seek re-election. In other words, the observed frequency of inefficient environmental policies should be higher during the first term than during the final term in jurisdictions where there are the term limits. This prediction of the model can be tested against the data. The analysis of such an issue would be a fruitful area for future research.

Figure 1: Timing of Events in the Game

Period 1	Incumbent observes own type η = risk of environmental damage ρ = incumbent's initial reputation σ = citizen's estimate of η and chooses (t, τ)
Election	Citizen observes ρ, σ λ = challenger's initial reputation (t, τ, h) = incumbent's first period record and vote
Period 2	Winner selects (t, τ)

Figure 2: Description of the Pooling Equilibrium

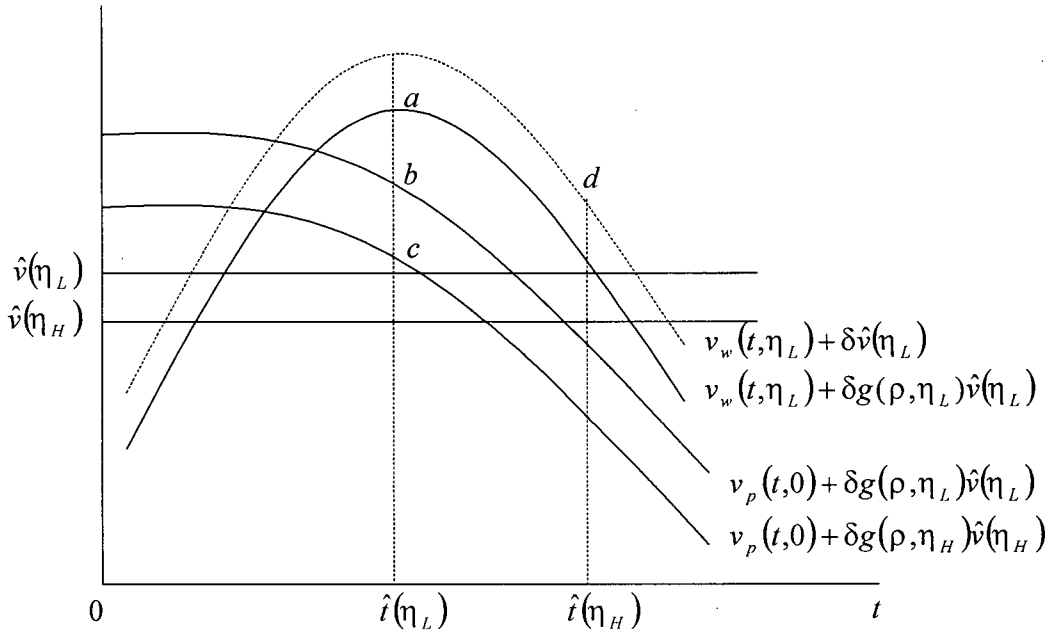


Figure 3: Description of the Separating Equilibrium

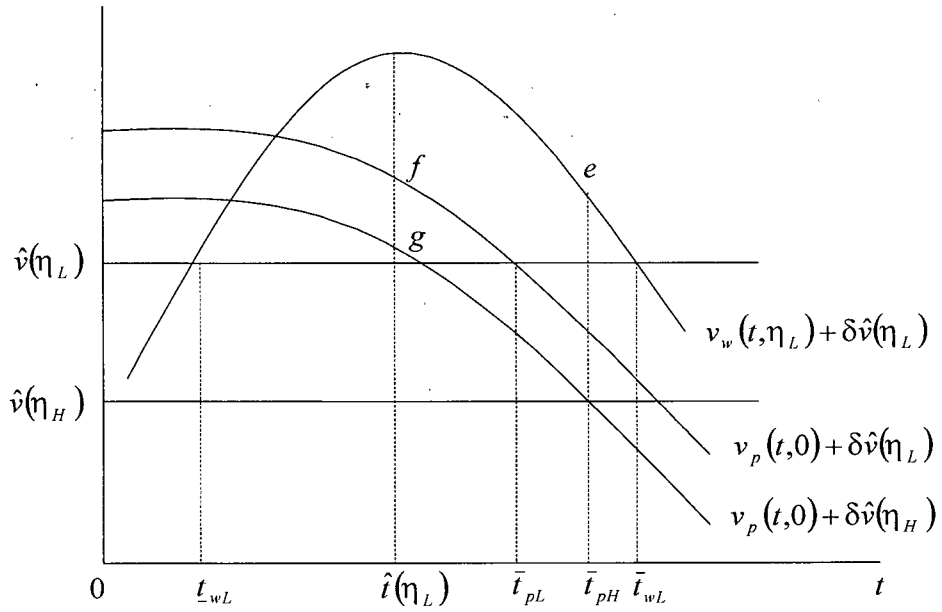
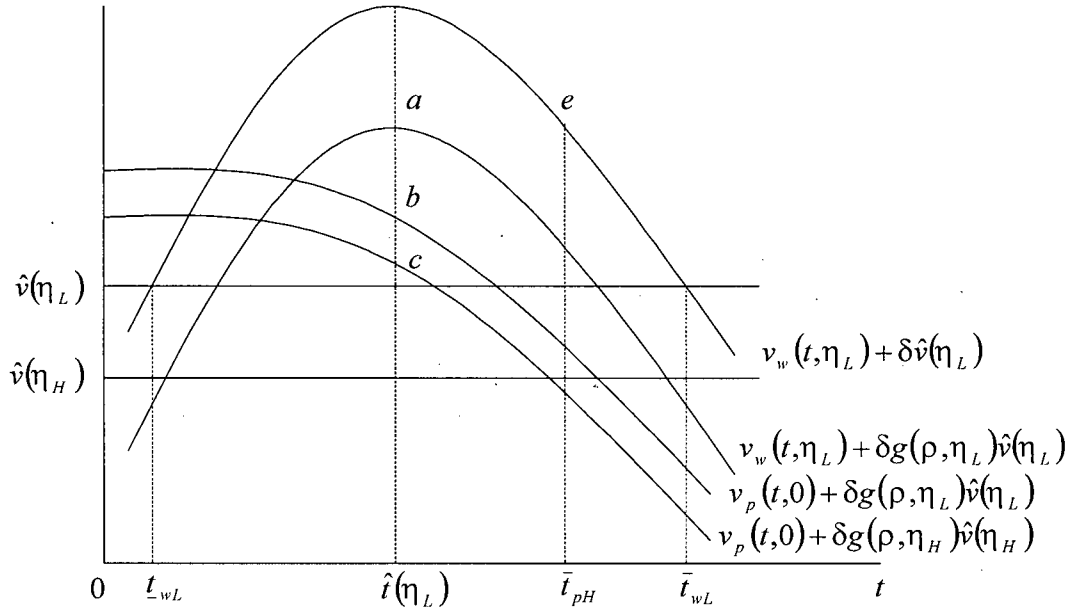


Figure 4: Selection of Equilibrium between the Pooling and the Least-distorting Separating Equilibria



Chapter 3

Trade Liberalization, Lobby Formation, and Environmental Policy

3.1 Introduction

Economic integration and its resulting environmental problems during the last decade brought much attention to the question of whether free trade is good for the environment. It is often argued that freer trade causes an expansion of polluting industries in a country that has a comparative advantage in those goods and hence results in environmental degradation. It is further argued that increased income levels brought about by trade can generate a demand for a better quality of environment.[22] Given that the determination of environmental policy is subject to political pressures,[23] the question is why political pressure for environmental protection is so weak in the earlier stages of trade and growth, and how further openness to trade can generate a political pressure that demands a stringent environmental regulation.

The purpose of this essay is to construct a political economy model in which the formation of lobby groups and environmental policy are endogenously determined and investigate how one country's decision to liberalize trade will have an impact on the political-economic structure that chooses the environmental policy in another country. First, it will be shown that a unilateral tariff reduction by a large country importing a dirty good will generate an industry lobby and hence reduce the stringency of environmental regulation in a small country exporting that good in the earlier stages of trade liberalization. Second, for a pre-existing lobby, unilateral trade liberalization by the large country will be shown to generate its rival lobby in the small country. A formulated rival lobby will compete effectively with

[22] See Grossman and Krueger (1993) for their NAFTA study. One recent example is the Chinese experience. Expansion of polluting industries has brought about serious environmental problems in China. However recently, the Chinese government has dramatically increased its spending on environmental protection. See *The Economist*, August 21st, 2004 for detail.

[23] See Coates (1996) and Cropper et al. (1992) for detailed discussions on this issue.

the existing lobby to oppose an initially distorted environmental regulation.

Finally, using numerical simulations, the unilateral tariff reduction by the large country will be shown to cause a formation of an industry lobby rather than an environmental lobby and further reductions of trade barriers will generate an environmental lobby in the small country. Therefore, the prediction of this study is that in the initial process of trade liberalization a political pressure to reduce stringency of environmental regulation is stronger but further increase in the openness to trade will generate an opposite force that demand stronger environmental protection.

The result in this essay is consistent with the political forces behind the inverse U-shaped relationship between trade, growth, and the environment known as the Environmental Kuznets Curve. Moreover, the framework of this essay provides an alternative view of the Environmental Kuznets Curve.[24] That is, it claims that the positive relationship between the pollution and income in the earlier stages of trade and growth is not only due to the scale effect but due to the presence of a too lax environmental regulation that is caused by the emergence of an industry lobby, and the negative relationship in the later stage is not only due to the income effect but due to the presence of a too stringent environmental policy that is caused by the emergence of an environmental lobby.

There are several studies examining the effect of trade liberalization on the environmental policy in a political economic framework. Bommer and Schulze (1999) examine this issue in a model in which the government maximizes the *political support function.*[25] They show that the dirty good exporter will always tighten up an environmental regulation in response to trade liberalization. Fredriksson (1999) examines the same question in a model of exogenous lobby formation, and shows that freer trade reduces incentives for lobbying activity in a small country exporting a dirty good. Damania et al. (2003) focus on corruption in examining this question and show that increased corruption reduces the stringency of environmental policy.

[24] The standard Environmental Kuznets Curve story is that the pollution first rises with increasing income levels by expanding an economy's scale, but further economic growth will reduce the amount of pollution by stimulating the demand for a better quality of environemt.

[25] Political support function is an exogenously given government welfare function that has as its arguments interest group's welfare and the deadweight loss imposed on society. Thus, they do not consider lobby groups and their formations.

Therefore, all these studies focus on static aspects of the effect of trade on environmental policy. On the other hand, this essay focuses on the dynamic structure of lobby formation and hence can generate the dynamic change in environmental policy in response to trade liberalization as empirical evidence suggests.

Studies concerning the endogenous lobby formation include Mitra (1999) and Krishna and Mitra (2005). Applying the political economy model of Grossman and Helpman (1994), Mitra (1999) develops a political economy model of endogenous lobby formation to examine equilibrium structure of trade protections. Krishna and Mitra (2005) apply the model of endogenous lobby formation by Mitra (1999) to examine whether unilateral trade liberalization by one country can induce reciprocal liberalization by another country.

This essay is organized as follows. The next section sets up a political economy model of endogenous formation of lobby groups and environmental policy that will be used throughout the essay. Section 3.3 solves the model and characterizes the political equilibrium. Section 3.4 analyzes the impact of unilateral trade liberalization on the equilibrium structure of lobby groups and the environmental policy. Section 3.5 undertakes numerical simulations. The final section concludes the essay.

3.2 The Model

This section sets up a political economy model in which the formation of lobby groups and the environmental policy are endogenously determined.[26] Consider a small open economy that has two sectors; a non-polluting numeraire good z and a polluting good x. This small country (home) has a comparative advantage in producing good x and exports it to the large partner country (foreign) whose imports are restricted by an import tariff. This essay focuses on the home country and therefore takes the foreign as passive.

[26] Mitra (1999) originally developed the political economy model of endogenous lobby formations to study the structure of trade protections.

3.2.1 Production

The production side of the economy is described by a specific factors model of a small open economy that is frequently used in the theory of international trade.[27] Non-polluting numeraire good z is produced by labor with constant returns to scale technology. Unit input-output coefficient is assumed. On the other hand, polluting good x is produced by labor and an inelastically supplied specific factor with constant returns to scale technology. The production function of good x is represented by the Cobb-Douglas form,

$$x = F(l_x, K) = l_x^{\alpha} K^{1-\alpha}, \ \alpha \in (0,1),$$

where l_x is the amount of labor in x sector, and K is the amount of inelastically-supplied specific factor. Each unit of production of good x generates one unit of pollution which negatively affects the individual's utility.[28] Assuming both goods are produced in equilibrium, equilibrium wage rate becomes equal to one, and hence the supply of good x depends only on its producer price p, that is, $x(p)$, where $x' > 0$. The production of good x is subject to a pollution tax τ so that $p = p^* - \tau$, where p^* is the world price of good x. The reward to the specific factor also becomes dependent only on p, and can be written as $\pi(p)$. Application of Hotelling's lemma gives the relationship, $x(p) = \pi'(p)$.

3.2.2 Individuals

There are three types of individuals in the economy; *environmentalists* (E), *industrialists* (I), and *workers* (W). All types supply labor inelastically and obtain labor income, whereas only industrialists own the specific factor used in the production of good x and obtain its reward as a factor income. All types share identical preferences over consumption of two goods, c_z, c_x, but have different preferences over the environmental damage caused by the production of x. The preference of an individual of type i $(= E, I, W)$ can be represented by the utility

[27] For detailed discussions on the specific factors model, see Dixit and Norman (1980), and Woodland (1982).

[28] For simplicity, production externalities such that the production of good x negatively affects productivity are excluded. For studies dealing with this issue see, for example, Copeland and Taylor (1999).

function of $u_i = c_z + u(c_x) - h_i(x)$. The function h_i represents the environmental damage that the type i individual suffers from pollution and depends positively on the amount of pollution (or equivalently the production of x). Assume for simplicity that h_i takes a linear form of $h_i(x) = \eta_i x$, where $\eta_i > 0$. Thus, η_i can be interpreted as the marginal damage from pollution. Assume that $\eta_E \geq \eta_I \geq \eta_W$, that is, the environmentalists have the highest concerns over the environment, the industrialists the second, and the workers the least.[29] The sub-utility function $u(\cdot)$ is assumed to be increasing and strictly concave.

Type i individual's utility maximization problem can be stated as follows.

$$\max_{c_z, c_x} u_i = c_z + u(c_x) - \eta_i x,$$
$$s.t.\ y_i = c_z + p^* c_x,$$

where y_i is the type i individual's net income. From the first-order conditions, the demand for good x can be obtained as

$$c_x = c_x(p^*),$$

where the function $c_x(\cdot)$ is the inverse of $u'(\cdot)$. The demand for good z is

$$c_z = y_i - p^* c_x(p^*).$$

The indirect utility function for type i individual can be obtained by substituting these into u_i,

$$v^i(\tau, p^*) = y_i + s(p^*) - \eta_i x(p^* - \tau), \tag{11}$$

where $s(p^*) = u[c_x(p^*)] - p^* c_x(p^*)$ represents the consumer surplus and is a function of the world price of good x.

[29] One implication for the assumption $\eta_I \geq \eta_W$ is that individuals with relatively higher incomes (industrialists) demand for a better quality of environment.

3.2.3 Net Incomes and Indirect Utilities

The economy consists of many identical environmentalists, industrialists, and workers. The total number of the population is normalized to one. Let θ_E and θ_I denote the fraction of environmentalists and industrialists in the total population, respectively.[30] Let l be each individual's endowment of labor. Thus, the equilibrium labor income each individual receives is l as both goods are assumed to be produced in equilibrium. Assume that the ownership of the specific factor be entirely symmetric so that each industrialist receives an amount of π/θ_I as a factor income. Revenue from the pollution tax is given by

$$r(\tau, p^*) = \tau x(p^* - \tau),$$

which is assumed to be uniformly rebated to all individuals.

Thus, per-capita income for an environmentalist and a worker is given by

$$y_E = y_W = l + r(\tau, p^*),$$

and that for an industrialist is given by

$$y_I = \frac{\pi(p^* - \tau)}{\theta_I} + l + r(\tau, p^*).$$

The indirect utility for each individual type can be obtained by substituting y_E, y_I and y_W above into (11),

$$v^E(\tau, p^*) = l + r(\tau, p^*) + s(p^*) - \eta_E x(p^* - \tau),$$

$$v^I(\tau, p^*) = \frac{\pi(p^* - \tau)}{\theta_I} + l + r(\tau, p^*) + s(p^*) - \eta_I x(p^* - \tau),$$

$$v^W(\tau, p^*) = l + r(\tau, p^*) + s(p^*) - \eta_W x(p^* - \tau).$$

[30] Therefore, the fraction of workers is $(1 - \theta_E - \theta_I)$.

Thus, aggregate welfare for a group of environmentalists, gross of political contributions, can be written as

$$V^E(\tau, p^*) = \theta_E \left[l + r(\tau, p^*) + s(p^*) - \eta_E x(p^* - \tau) \right], \tag{12}$$

and that for a group of industrialists can be written as

$$V^I(\tau, p^*) = \pi(p^* - \tau) + \theta_I \left[l + r(\tau, p^*) + s(p^*) - \eta_I x(p^* - \tau) \right]. \tag{13}$$

Aggregate welfare for a group of workers can be written as

$$V^W(\tau, p^*) = (1 - \theta_E - \theta_I) \left[l + r(\tau, p^*) + s(p^*) - \eta_W x(p^* - \tau) \right]. \tag{14}$$

Aggregate social welfare, gross of political contributions, is the sum of V^E, V^I and V^W.

$$V^A(\tau, p^*) = \pi(p^* - \tau) + l + r(\tau, p^*) + s(p^*) - \overline{\eta} x(p^* - \tau). \tag{15}$$

where $\overline{\eta} = \theta_E \eta_E + \theta_I \eta_I + (1 - \theta_E - \theta_I)\eta_W$. It represents the weighted average of each individual type's marginal damage from pollution and hence can be interpreted as the social marginal damage.

3.2.4 Government

The government preference in this model is similar to that in Grossman and Helpman (1994), and others. In particular, the government cares about the political contributions it receives as well as the aggregate social welfare. The government cares about the political contributions because they can be used to finance spending on the political campaigns. Also, the government concerns itself about the aggregate social welfare because higher aggregate social welfare is more likely to result in an electoral win in the future. Thus, the government's

objective function is given by the following linear form.

$$V^G(\tau, p^*) = \sum_{j \in L} C^j(\tau, p^*) + aV^A(\tau, p^*), \tag{16}$$

where L is the set of organized lobby groups, $C^j(\tau, p^*)$ represents the contribution schedule of lobby group j, and a represents the degree of how the government cares about the aggregate social welfare relative to the political contributions. That is, the government seeks to maximize the weighted sum of the political contributions and the aggregate social welfare.

3.3 Endogenous Formation of Lobby Groups and Environmental Protection

The game under consideration, as in Mitra (1999), is a three-stage non-cooperative game in which the formation of lobby groups and government policy can be endogenously determined. The timings of the decisions are as follows. In the first stage of the game, each individual of type j decides whether to contribute to the fixed cost of lobby formation F^j. As in Mitra (1999), this fixed cost can include any costs incurred for establishing and maintaining such an organization. Note that the resources for the fixed cost come from labor. Thus, under sufficiently larger amount of labor, the lobby formation just reduces the output of the numeraire.

Individuals who share similar interests have incentives to organize a lobby group. Thus, an environmentalist will have an incentive to join an environmental lobby, while an industrialists has an incentive to join an industry lobby. For simplicity, assume that workers face a sufficiently larger cost of lobby formation F^W so that their benefit from lobby formation is sufficiently smaller than F^W.[31] In the second stage, organized lobby groups choose their political contribution schedules. In the third stage, the government chooses environmental policy to maximize its objective function (16).

[31] This essay considers the situation in which the fixed cost F^j depends positively on the group size θ_j, and the number of workers is sufficiently larger relative to environmentalists and industrialists. Thus, the assumption that the workers do not form the lobby follows.

This three-stage game can be solved by backward induction. In the third stage of the game, the government chooses environmental policy to maximize its objective function (16), taking the contribution schedules offered by organized lobbies as given. That is, the government solves

$$\max_{\tau \in T} V^G(\tau, p^*) = \sum_{j \in L} C^j(\tau, p^*) + aV^A(\tau, p^*),$$

where T is the set of pollution taxes from which the government can choose. As in Grossman and Helpman (1994), the focus here is the case in which the equilibrium environmental policy lies in the interior of T.[32]

In the second stage of the game, organized lobbies choose their contribution schedules. As in Grossman and Helpman (1994), it is assumed that the contribution schedules chosen by any organized lobbies reflect their true preferences. That is, the organized lobby always chooses a truthful contribution schedule that is represented by

$$\hat{C}^j(\tau, p^*) = \max\left\{0, V^j(\tau, p^*) - B_j\right\}.$$

for a lobby j. A scalar B_j can be interpreted as the net welfare of lobby j if the lobby makes positive contributions, and is called the " net welfare anchors " for lobby j. The equilibrium in which organized lobbies always make positive contributions is now focused on. Thus, under any truthful Nash equilibria (Nash equilibria in which organized lobbies choose truthful contribution schedules), the equilibrium pollution tax $\hat{\tau}$ satisfies

$$\hat{\tau} = \arg\max_{\tau} \sum_{j \in L} V^j(\tau, p^*) + aV^A(\tau, p^*).$$

In particular, $\hat{\tau}$ can be implicitly derived as

$$\hat{\tau}(p^*) = \overline{\eta} + \frac{\sum_{j \in L} \theta_j \eta_j - \gamma\overline{\eta} - (I - \gamma)x/x'}{a + \gamma}, \tag{17}$$

where $x' = \partial x / \partial p$, γ is a proportion of population that belongs to any organized lobby in

[32] This guarantees the existence of an equilibrium in this type of the game. See Bernheim and Whinston (1986) for detailed discussions on this issue.

equilibrium, and I is an indicator variable that is one if industrialists are organized and zero otherwise. Note that in general $\hat{\tau}$ is a function of the world price of good x. Equation (17) states that in the presence of political pressure the government's choice of environmental policy deviates from the level that fully internalizes the pollution externalities, that is, the efficient Pigovian taxes. The first term on the right-hand side of (17) is the social marginal damage from pollution. The second term is called the political support term. The sign of this term depends on the equilibrium structure of lobby formation. For example, suppose that no lobby is formed in equilibrium. This implies that $I = \gamma = 0$, and hence (17) gives

$$\hat{\tau} = \overline{\eta},$$

that is, if no individual is organized in equilibrium, the political support term in (17) will disappear and the equilibrium pollution tax coincides with the social marginal damage from pollution.

Next, suppose that only environmentalists are organized in equilibrium. In this case, $I = 0$ and $\gamma = \theta_E$, and hence (17) gives

$$\hat{\tau}_E = \overline{\eta} + \frac{\theta_E(\eta_E - \overline{\eta}) + \theta_E x/x'}{a + \theta_E},$$

where the subscript E means only environmentalists are organized in equilibrium. Note that $\eta_E > \overline{\eta}$ as $\eta_E \geq \eta_I \geq \eta_W$. This, together with $x' > 0$, implies that $\hat{\tau}_E > \overline{\eta}$, that is, in the presence of an environmental lobby the equilibrium pollution tax exceeds the marginal damage from pollution.

On the other hand, if only industrialists are organized in equilibrium, this implies $I = 1$ and $\gamma = \theta_I$, and hence (17) gives

$$\hat{\tau}_I = \overline{\eta} + \frac{\theta_I(\eta_I - \overline{\eta}) - (1 - \theta_I)x/x'}{a + \theta_I}.$$

where the subscript I means only industrialists are organized in equilibrium. Whether $\hat{\tau}_I$ exceeds or is below $\overline{\eta}$ is ambiguous and depends on how industrialists care about the envi-

ronment. In particular, if $\eta_I < \overline{\eta} + \frac{1-\theta_I}{\theta_I}\frac{x}{x'}$, then $\hat{\tau}_I$ is below the social marginal damage from pollution, and vice versa.

If both groups are organized in equilibrium, this implies $I = 1$ and $\gamma = \theta_E + \theta_I$, and hence (17) gives

$$\hat{\tau}_{E,I} = \overline{\eta} + \frac{\sum_{j \in E,I} \theta_j(\eta_j - \overline{\eta}) - (1 - \theta_E - \theta_I)x/x'}{a + \theta_E + \theta_I},$$

where the subscript E, I means both lobbies are organized in equilibrium. Again, whether $\hat{\tau}_{E,I}$ exceeds or is below $\overline{\eta}$ is ambiguous and depends on how both environmentalists and industrialists care about the environment. Therefore, the above expressions reveal that the presence of at least one lobby group is the source of distortions in this model.

Finally, in the first stage of the game, each environmentalist and industrialist decides whether to form an organized lobby. As mentioned above, to form the lobby, each group faces the fixed cost of lobby formation. As in Mitra (1999), when deciding whether to contribute to finance the fixed cost of lobby formation or not, individuals within groups behave in a Nash fashion. However, once they decide to form the lobby, they coordinate perfectly in collecting political contributions. As individuals within groups are assumed to be identical, they contribute an equal amount of political contributions.

Now consider conditions under which one group can be organized taking the other as given (organized or unorganized).[33] Denote $\hat{V}^j_{E,I}$ as equilibrium gross welfare of group j $(= E, I)$ when both lobbies are in place, $\hat{V}^j_k$ as that when only lobby k $(= E, I)$ is in place, and $\hat{V}^j$ when no lobby in place. Also, denote $\hat{C}^j_{j,k}$ as lobby j's equilibrium political contributions taking its rival k as organized and $\hat{C}^j_j$ as that taking its rival k as unorganized. Therefore, as in Mitra (1999), depending on the equilibrium structure of lobby formation, the condition under which a lobby is formed can be written as follows. First, the condition under which lobby j is formed taking its rival k as unorganized is

$$\hat{V}^j_j - \hat{V}^j - \hat{C}^j_j > F^j. \tag{18}$$

[33] That is, lobby j takes its rival k as organized (unorganized) if k is organized (unorganized) initially.

Second, the condition under which lobby j is formed taking lobby k as organized is

$$\hat{V}^j_{j,k} - \hat{V}^j_k - \hat{C}^j_{j,k} > F^j. \tag{19}$$

The left-hand side of (18) and (19) represents the net benefit to group j from forming an organized lobby while the right-hand side is the fixed cost of lobby formation. For lobby j to be organized, the net benefit of lobby formation must exceed its cost. If this condition is satisfied, Nash interactions among all group j individuals will generate the equilibrium outcome that the fixed cost F is fully financed and the lobby j is formed. Having described the initial equilibrium and derived conditions under which the lobby is formed, the next section will examine the effect of unilateral trade liberalization by a foreign country on the domestic political equilibrium.

3.4 Trade Liberalization and the Choice of Environmental Regulation

This section examines how unilateral tariff reductions by the large foreign country, leading to a price change, affect equilibrium structures of lobby formation and environmental policy in the home country. In particular, this section examines how a change in p^* affects the net benefit from lobby formation for the home environmentalists and industrialists. As the home country exports the polluting good x and the foreign country restricts its import by tariff, the unilateral tariff reductions by the large foreign country will result in an increase in p^*.

This section makes additional assumptions for analytical tractability. First, lets assume that the supply function of the polluting good x takes a linear form, that is $\alpha = 1/2$ in the production function of good x.[34] Second, lets assume that all individual types equally care about the environment, that is, $\eta_j = \eta$, for $j = E, I, W$.[35] Third, lets assume that the

[34] Fredriksson (1997) implicitly adopts this form by assuming that the second derivative of the supply function is zero.

[35] Thus in this case, all individual types share identical preferences over the environmental damage as well as the consumption of the two goods.

fixed cost of lobby formation is the same across environmentalists and industrialists, that is, $F^j = F$, for $j = E, I$. With these assumptions, the political equilibrium pollution tax rate can be explicitly solved and the sign of $\tau - \eta$ can be determined. Notice that (17) is now written by

$$\hat{\tau}(p^*) = \eta - \frac{I - \gamma}{a + \gamma} \frac{x}{x'}.$$

First, suppose that no lobby is formed in equilibrium. That is, using $I = \gamma = 0$ to obtain

$$\hat{\tau} = \eta. \tag{20}$$

Next, if only environmentalists are organized in equilibrium, then $I = 0$ and $\gamma = \theta_E$, and hence

$$\hat{\tau}_E = \eta + \frac{\theta_E}{a + \theta_E} \frac{x}{x'} = \frac{\theta_E p^* + (a + \theta_E)\eta}{\theta_E + (a + \theta_E)} \quad (> \eta), \tag{21}$$

where the last inequality follows from $x' > 0$. On the other hand, if only industrialists are organized in equilibrium, then $I = 1$ and $\gamma = \theta_I$, and hence

$$\hat{\tau}_I = \eta - \frac{1 - \theta_I}{a + \theta_I} \frac{x}{x'} = \frac{(1 - \theta_I)p^* - (a + \theta_I)\eta}{(1 - \theta_I) - (a + \theta_I)} \quad (< \eta), \tag{22}$$

where, again, the inequality holds as $x' > 0$. Finally, if both groups are organized in equilibrium, then $I = 1$ and $\gamma = \theta_E + \theta_I$, and hence

$$\hat{\tau}_{E,I} = \eta - \frac{1 - \theta_E - \theta_I}{a + \theta_E + \theta_I} \frac{x}{x'} = \frac{(1 - \theta_E - \theta_I)p^* - (a + \theta_E + \theta_I)\eta}{(1 - \theta_E - \theta_I) - (a + \theta_E + \theta_I)} \quad (< \eta), \tag{23}$$

where the last inequality holds by the same reason as above.

3.4.1 No Lobby Formed Initially

Suppose that initially no group is organized because of the fixed cost of lobby formation. Thus, initially efficient environmental policy $\hat{\tau}$ is in place. In this case, which group is more likely to form an organized lobby first in response to the unilateral tariff reduction by the foreign country?

Denote NB^j as the net benefit to group j from forming an organized lobby. That is,

$$\begin{aligned} NB^j &= \hat{V}_j^j - \hat{V}^j - \hat{C}_j^j, \\ &= V^j(\hat{\tau}_j, p^*) - V^j(\hat{\tau}, p^*) - \hat{C}^j(\hat{\tau}_j, p^*). \end{aligned} \tag{24}$$

Note that NB^j is net of political contributions but gross of fixed costs. Note also that NB^j is a function of p^* only.[36] Thus, the assumption that no lobby is formed initially implies that at initial p^* $NB^j < F$ for both groups ($j = E, I$). Focusing on truthful Nash equilibria (TNE) with positive contributions, the contribution schedule chosen by lobby j in equilibrium can be written as

$$\hat{C}^j(\hat{\tau}_j, p^*) = V^j(\hat{\tau}_j, p^*) - B_j,$$

for some scalar B_j. It is known that with truthful contributions lobby j will raise B_j (that is, try to minimize C^j as small as possible) to the point where the government is just indifferent between choosing $\hat{\tau}$ and choosing $\hat{\tau}_j$.[37] In particular, lobby j chooses B_j and hence C^j such that the following holds.

$$aV^A(\hat{\tau}, p^*) = \hat{C}^j(\hat{\tau}_j, p^*) + aV^A(\hat{\tau}_j, p^*).$$

This can be re-written as

$$\hat{C}^j(\hat{\tau}_j, p^*) = a\left[V^A(\hat{\tau}, p^*) - V^A(\hat{\tau}_j, p^*)\right]. \tag{25}$$

Substitute (25) into (24) to re-write the net benefit function as

$$\begin{aligned} NB^j &= V^j(\hat{\tau}_j, p^*) - V^j(\hat{\tau}, p^*) - a\left[V^A(\hat{\tau}, p^*) - V^A(\hat{\tau}_j, p^*)\right], \\ &= V^j(\hat{\tau}_j, p^*) + aV^A(\hat{\tau}_j, p^*) - \left[V^j(\hat{\tau}, p^*) + aV^A(\hat{\tau}, p^*)\right], \end{aligned}$$

that is, net benefit to group j from forming an organized lobby is the difference between

[36] This is because $\hat{\tau}_j$ depends only on p^*.

[37] See section IV in Grossman and Helpman (1994) for detailed discussions on this issue.

what the society and itself could jointly achieve when lobby j is in place and what the two actually attain when no lobby is in place. For each group, this net benefit function can be obtained by using (12)-(15).

$$\begin{aligned} NB^I &= \pi(p^* - \hat{\tau}_I) - \pi(p^* - \overline{\eta}) \\ &\quad +\theta_I \left[(\hat{\tau}_I - \eta_I)x(p^* - \hat{\tau}_I) - (\overline{\eta} - \eta_I)x(p^* - \overline{\eta})\right] \\ &\quad +a \left[\pi(p^* - \hat{\tau}_I) - \pi(p^* - \overline{\eta}) + (\hat{\tau}_I - \overline{\eta})x(p^* - \hat{\tau}_I)\right], \end{aligned}$$

$$\begin{aligned} NB^E &= \theta_E \left[(\hat{\tau}_E - \eta_E)x(p^* - \hat{\tau}_E) - (\overline{\eta} - \eta_E)x(p^* - \overline{\eta})\right] \\ &\quad +a \left[\pi(p^* - \hat{\tau}_E) - \pi(p^* - \overline{\eta}) + (\hat{\tau}_E - \overline{\eta})x(p^* - \hat{\tau}_E)\right]. \end{aligned}$$

The objective in this section is to examine how an increase in p^* brought about by unilateral tariff reduction by the foreign country affects each group's incentive to form an organized lobby. As mentioned above, NB^j is affected by p^* both directly and indirectly through $\hat{\tau}_j$. In addition, it depends on other parameters such as θ_I, θ_E, a, and η. The first set of propositions in this essay is about how these parameters affect the net benefit from lobby formation. First, consider the effect on the industrialist's incentives to form the lobby. Under the production and preference structures assumed above, the net benefit function for industrialists can be written as

$$NB^I = \frac{K(1-\theta_I)^2 (p^* - \eta)^2}{4(a + 2\theta_I - 1)}. \tag{26}$$

Thus, the following proposition with regard to the effect of θ_I, θ_E, a, η on NB^I can be obtained.

Proposition 5 : The net benefit from lobby formation for industrialists NB^I is (1) decreasing in the number of industrialists themselves θ_I, (2) not affected by the number of environmentalists θ_E, (3) decreasing in the government's weight on aggregate social welfare a, and (4) decreasing in the marginal damage from pollution η.

Proof: See Appendix B.

Intuitions for proposition 5 are as follows. Increasing the number of industrialists implies that they become more careful about the environmental distortions. This will increase environmental loss they suffer from the implementation of insufficient environmental regulations $\hat{\tau}_I$, and hence reduce their incentives for lobby formation. On the other hand, increasing the number of environmentalists has no effect on industrialist's behavior since their incentives to form the lobby do not depend on the number of environmentalists. If the government puts more weight on aggregate social welfare relative to the political contributions, it will require a greater amount of political contributions necessary to give protections. This will reduce incentives to form the lobby. That is, the more corrupt the government becomes (that is, smaller a), the greater the incentives are for industrialists to become organized. An increase in the marginal damage from pollution η will increase environmental loss for industrialists from the implementation of insufficient environmental regulation $\hat{\tau}_I$. This will also increase the necessary amount of political contributions to obtain protections. These two effects will reduce incentives to form the lobby for industrialists.

Next, consider the effect on the environmentalist's incentives to form the lobby. Again, under the production and preference structures assumed above, the net benefit function for environmentalists can be written as

$$NB^E = \frac{K\theta_E{}^2 \left(p^* - \eta\right)^2}{4(a + 2\theta_E)}. \tag{27}$$

The following proposition with regard to the effect of θ_I, θ_E, a, η on NB^E can be obtained.

Proposition 6 : The net benefit from lobby formation for environmentalists NB^E is (1) increasing in the number of environmentalists themselves θ_E, (2) not affected by the number of industrialists θ_I, (3) decreasing in the government's weight on aggregate social welfare a, and (4) decreasing in the marginal damage from pollution η.

Proof: See Appendix C.

Intuitions for proposition 6 are as follows. Increasing the number of environmentalists raises the gain from the implementation of tougher environmental regulations $\hat{\tau}_E$, and hence

increases their incentives to form the lobby. On the other hand, increasing the number of industrialists has no effect on environmentalist's behavior since their incentives to form the lobby do not depend on the number of industrialists. As in the case of industrialists, if the government puts more weight on aggregate social welfare relative to the political contributions, it will increase the amount of political contributions necessary to give protections, and hence reduce environmentalist's incentives to form a lobby. An increase in the marginal damage from pollution η will reduce the gain from $\hat{\tau}_E$, and also increase the necessary amount of political contributions to obtain protections. Those two effects will reduce the environmentalist's incentives to form a lobby.

Now, lets examine how an increase in p^* affects each group's net benefit from lobby formation. First, differentiating NB^j with respect to p^* gives

$$\frac{dNB^j}{dp^*} = \frac{\partial NB^j}{\partial p^*} + \frac{\partial NB^j}{\partial \hat{\tau}_j}\frac{d\hat{\tau}_j}{dp^*}. \tag{28}$$

However, it can be easily shown that

$$\frac{\partial NB^j}{\partial \hat{\tau}_j} = \frac{\partial}{\partial \hat{\tau}_j}\left[V^j(\hat{\tau}_j, p^*) + aV^A(\hat{\tau}_j, p^*)\right] = 0,$$

for $j = E, I$. Therefore, (28) can be expressed as

$$\begin{aligned}
\frac{dNB^I}{dp^*} &= \frac{\partial NB^I}{\partial p^*} \\
&= \underbrace{x(p^* - \hat{\tau}_I) - x(p^* - \overline{\eta})}_{PS} \\
&\quad \underbrace{+\theta_I\left[(\hat{\tau}_I - \eta_I)x'(p^* - \hat{\tau}_I) - (\overline{\eta} - \eta_I)x'(p^* - \overline{\eta})\right]}_{ED} \\
&\quad \underbrace{+a\left[x(p^* - \hat{\tau}_I) - x(p^* - \overline{\eta}) + (\hat{\tau}_I - \overline{\eta})x'(p^* - \hat{\tau}_I)\right]}_{PC},
\end{aligned} \tag{29}$$

for industrialists, and

$$\frac{dNB^E}{dp^*} = \frac{\partial NB^E}{\partial p^*}$$

$$= \underbrace{\theta_E\left[(\hat{\tau}_E - \eta_E)x'(p^* - \hat{\tau}_E) - (\overline{\eta} - \eta_E)x'(p^* - \overline{\eta})\right]}_{ED}$$
$$\underbrace{+a\left[x(p^* - \hat{\tau}_E) - x(p^* - \overline{\eta}) + (\hat{\tau}_E - \overline{\eta})x'(p^* - \hat{\tau}_E)\right]}_{PC}. \quad (30)$$

for environmentalists.

The term labeled PS on the right-hand-side of (29) represents the producer surplus effect. The sign of this term will be positive if $\hat{\tau}_I < \overline{\eta}$.[38] An increase in p^* will encourage industry lobby formation if the producer surplus when they are organized is greater than that when they are not. The term labeled ED on the right-hand-side of (29) and (30) represents the environmental distortions effect. An increase in p^* will encourage lobby formation if the environmental distortions when they are organized is smaller than that when they are not.

The term labeled PC on the right-hand-side of (29) and (30) represents the political contributions effect. This term can be decomposed into two effects. The first is the producer surplus effect. The sign of this term will be positive for NB^j if $\hat{\tau}_j < \overline{\eta}$. An increase in p^* will reduce the amount of political contributions to obtain protections and hence encourage lobby formation if the producer surplus when they are organized is greater than that when they are not. The second is the environmental distortions effect. The sign of this term will be negative for NB^j if $\hat{\tau}_j < \overline{\eta}$. An increase in p^* will increase the necessary amount of political contributions and hence discourage lobby formation if the environmental distortions when they are organized is greater than that when they are not.

The total effect is ambiguous and depends on the relative magnitude of those effects. However, under the production and preference structures assumed above, the sign of dNB^i/dp^* can be determined. The following lemma deals with this issue.

Lemma 4 : The net benefit from lobby formation for both environmentalists and industri-

[38] This follows from $x' > 0$.

alists is increasing in the world price of the polluting good x. That is, $dNB^I/dp^* > 0$ and $dNB^E/dp^* > 0$.

Proof: Differentiating (26) with respect to p^* to obtain

$$\frac{dNB^I}{dp^*} = \frac{K(1-\theta_I)^2\,(p^*-\eta)}{2(a+2\theta_I-1)}.$$

It can be shown that $a + 2\theta_I - 1 > 0$ to have $\hat{\tau}_I < \eta$ in (22). Also, $p^* - \eta = p^* - \hat{\tau} > 0$ to have a positive producer price. Thus, $dNB^I/dp^* > 0$.

Next, differentiating (27) with respect to p^* to obtain

$$\frac{dNB^E}{dp^*} = \frac{K\theta_E^2\,(p^*-\eta)}{2(a+2\theta_E)}$$

As $p^* - \eta > 0$, it follows that $dNB^E/dp^* > 0$. Q.E.D.

Lemma 4 states that the net benefit from lobby formation for both industrialists and environmentalists is an increasing function of the world price of the polluting good. That is, both groups will have an incentive to form organized lobbies in response to the unilateral tariff reduction by the foreign country that leads to an increase in p^*.[39]

Next, NB^I needs to be compared with NB^E for a given p^*. That is, the sign of the difference between NB^I and NB^E, $\Delta NB \equiv NB^I - NB^E$ is examined. The following lemma with regard to the sign of ΔNB can be obtained.

Lemma 5 : The net benefit to industrialists from forming an organized lobby for a given p^* will be greater than that of environmentalists, i.e., $\Delta NB > 0$, if

$$(1-\theta_I)^2(a+2\theta_E) > \theta_E^2(a+2\theta_I-1). \tag{31}$$

[39]Notice that the case in which $\alpha = 1/2$ and $\eta_E = \eta_I = \eta_W$ is considered here for analytical simplicity. However, as shown in the numerical simulations in the next section, this result can still hold for alternative $\alpha \in (0,1)$ and $\eta_E \geq \eta_I \geq \eta_W$.

Proof: Using (26) and (27) to express ΔNB as

$$\Delta NB = \frac{K\left[(1-\theta_I)^2(a+2\theta_E) - \theta_E^2(a+2\theta_I-1)\right]}{4(a+2\theta_I-1)(a+2\theta_E)}(p^*-\eta)^2.$$

Note that $a + 2\theta_I - 1 > 0$ by the same reason as in lemma 4. Thus, $\Delta NB > 0$ if $(1-\theta_I)^2(a+2\theta_E) - \theta_E^2(a+2\theta_I-1) > 0$. Q.E.D.

Lemma 5 states that the net benefit to industrialists from forming an organized lobby is greater than that of environmentalists for a given p^* if the inequality (31) is satisfied. One implication for (31) is that increasing θ_I for given θ_E (and a) will decrease the left-hand-side but increase the right-hand-side. Thus, the more industrialists in the economy, the smaller their incentives to form a lobby relative to the environmentalists. On the other hand, for a given θ_I (and a), as θ_E becomes close to zero, so does the right-hand-side. Thus, the less environmentalists in the economy, the more incentives there are for industrialists to form the lobby.[40] Therefore, if industrialists and environmentalists comprise a sufficiently small fraction of the total population, the industrialist's incentives to form the lobby will be greater than the environmentalist's.

Now let $p^* = \bar{p}^j$ solve the equation $NB^j(p^*) = F$. Then, the following proposition can be obtained.

Proposition 7 : Suppose that industrialists and environmentalists comprise a sufficiently small fraction of the total population in a small country exporting a polluting good to a large country such that the following holds.

$$(1-\theta_I)^2(a+2\theta_E) > \theta_E^2(a+2\theta_I-1).$$

Then, it follows that $\bar{p}^I < \bar{p}^E$. If the unilateral tariff reductions by the large country raise p^* above $\bar{p}^I$ but not $\bar{p}^E$, then the small country's environmental policy becomes too weak from $\hat{\tau}$ to $\hat{\tau}_I$.

[40] As a special case, consider the situation in which the economy consists of only environmentalists (θ) and industrialists ($1-\theta$). Then, (31) reduces to $\theta > 1/4$. That is, if environmentalists comprise more than a quarter in total population, or equivalently, if industrialists comprise less than a quarter in total population, then the net benefit of lobby formation for industrialists is greater than that of environmentalists.

The above result follows from lemmas 4 and 5. Figure 5 describes this situation. If the unilateral tariff reductions by the large foreign country raise p^* above $\bar{p}^I$ but not $\bar{p}^E$, then home industrialists will be organized and lobby for weak environmental policy $\hat{\tau}_I(< \eta)$. Therefore, unilateral tariff reductions by a large country importing a dirty good will generate an industry lobby and hence reduce the stringency of environmental regulation in a small country exporting that good.

3.4.2 Lobby Formation in the Presence of Rival Lobby

The above section examines which lobby is formed in response to the unilateral tariff reduction by the large foreign country and concludes that if industrialists and environmentalists comprise a sufficiently small fraction of the total population so that (31) holds, then this unilateral tariff reduction will generate an industry lobby rather than an environmental lobby in the home country. The reason is because an increase in the world price of the polluting good that the unilateral tariff reduction causes will increase the home industrialist's net benefit more than environmentalist's.

In contrast to the previous discussion, this section examines the following question. Suppose that one group is organized while the other is not. Suppose further, that the pre-existing lobby always remains organized.[41] In this situation, how does a reduction of trade barriers have an impact on the unorganized group's incentives to form an organized lobby?

To answer this question, consider the net benefit to group j from lobby formation in the presence of its rival k. Using the same notation as before, this can be written as

$$\begin{aligned} NB^{j'} &= \hat{V}^j_{E,I} - \hat{V}^j_k - \hat{C}^j_{E,I}, \\ &= V^j(\hat{\tau}_{E,I}, p^*) - V^j(\hat{\tau}_k, p^*) - \hat{C}^j(\hat{\tau}_{E,I}, p^*). \end{aligned} \tag{32}$$

Under truthful Nash equilibria with positive contributions, the equilibrium contribution

[41] That is, this section considers the lobby formation of only one group.

schedule chosen by lobby j in the presence of lobby k can be written as

$$\hat{C}^j(\hat{\tau}_{E,I}, p^*) = V^j(\hat{\tau}_{E,I}, p^*) - B_j,$$

for some scalar B_j. As before, with truthful contributions lobby j in the presence of lobby k will choose B_j and hence $\hat{C}^j$ such that the government is indifferent between choosing $\hat{\tau}_k$ and choosing $\hat{\tau}_{E,I}$. That is,

$$\hat{C}^k(\hat{\tau}_k, p^*) + aV^A(\hat{\tau}_k, p^*) = \hat{C}^k(\hat{\tau}_{E,I}, p^*) + \hat{C}^j(\hat{\tau}_{E,I}, p^*) + aV^A(\hat{\tau}_{E,I}, p^*).$$

Note that lobby k also uses a truthful contribution schedule. Thus, the above equation can be re-written as

$$\begin{aligned} \hat{C}^j(\hat{\tau}_{E,I}, p^*) &= V^k(\hat{\tau}_k, p^*) + aV^A(\hat{\tau}_k, p^*) \\ &\quad - \left[V^k(\hat{\tau}_{E,I}, p^*) + aV^A(\hat{\tau}_{E,I}, p^*)\right]. \end{aligned} \tag{33}$$

That is, lobby j must contribute to the government an amount equal to the difference between what its rival k and society could jointly achieve when only lobby k is in place and what the two actually attain when both lobbies are organized. Now, substituting (33) into (32) to obtain,

$$\begin{aligned} NB^{j'} &= \hat{V}^j_{E,I} - \hat{V}^j_k - \left[\hat{V}^k_k + a\hat{V}^A_k - \left(\hat{V}^k_{E,I} + a\hat{V}^A_{E,I}\right)\right] \\ &= \hat{V}^j_{E,I} + \hat{V}^k_{E,I} + a\hat{V}^A_{E,I} - \left[\hat{V}^j_k + \hat{V}^k_k + a\hat{V}^A_k\right]. \end{aligned}$$

This equation states that the net benefit from lobby j formation in the presence of lobby k is equal to the difference between what the government, its rival and itself could jointly achieve when both lobbies are in place and what the three actually attain when only lobby k is in place.

3.4.3 Environmentalist's Incentives in the Presence of an Industry Lobby

Suppose that initially the industry lobby is in place while the environmental lobby is not. That is, $NB^{E'} < F$ for initial p^*. Using (12)–(15), $NB^{E'}$ can be written as

$$\begin{aligned} NB^{E'} &= (1+a)\left[\pi(p^* - \hat{\tau}_{E,I}) - \pi(p^* - \hat{\tau}_I)\right] \\ &\quad + (a + \theta_E + \theta_I)\left[(\hat{\tau}_{E,I} - \beta)\, x(p^* - \hat{\tau}_{E,I}) - (\hat{\tau}_I - \beta)\, x(p^* - \hat{\tau}_I)\right] \end{aligned}$$

where $\beta = (a\overline{\eta} + \theta_E\eta_E + \theta_I\eta_I) / (a + \theta_E + \theta_I)$. Note that $NB^{E'}$ is affected by p^* both directly and indirectly through $\hat{\tau}_{E,I}$ and $\hat{\tau}_I$. In addition, it depends on other parameters such as θ_I, θ_E, a, η. Again, consider how these parameters affect the net benefit from the environmental lobby formation in the presence of the industry lobby. Under the production and preference structures assumed above, the net benefit function for environmentalists in the presence of an industry lobby can be written as

$$NB^{E'} = \frac{K(a+1)^2\theta_E^2\,(p^* - \eta)^2}{4(a + 2\theta_I - 1)^2(a + 2\theta_I - 1 + 2\theta_E)}. \tag{34}$$

The following proposition with regard to the effect of θ_I, θ_E, a, η on $NB^{E'}$ can be obtained.

Proposition 8 : The net benefit from lobby formation for environmentalists in the presence of the industry lobby $NB^{E'}$ is (1) increasing in the number of environmentalists themselves θ_E, (2) decreasing in the number of industrialists θ_I, (3) decreasing in the government's weight on aggregate social welfare a, and (4) decreasing in the marginal damage from pollution η.

Proof: See Appendix D.

Perhaps the most interesting result might be (2), that is, the effect of increasing the number of industrialists. In the previous case in which no lobby is formed initially, increasing the number of industrialists has no impact on environmentalist's behavior. However here, for a pre-existing industry lobby, increasing the number of industrialists reduces the

net benefit from environmental lobby formation. An intuition is as follows. As discussed above, increasing the number of industrialists implies that they become more careful about the environmental distortions. This will strengthen an initially implemented too weak policy $\hat{\tau}_I$, and reduce environmental loss suffered when only the industry lobby is in place. This reduction will increase the necessary amount of political contributions, and hence discourage environmental lobby formation. Any other effects are qualitatively the same as in the previous case.

Now examine how an increase in p^* brought about by unilateral tariff reductions affects the net benefit from environmental lobby formation. To do so, differentiate $NB^{E'}$ with respect to p^* to obtain

$$\frac{dNB^{E'}}{dp^*} = \frac{\partial NB^{E'}}{\partial p^*} + \frac{\partial NB^{E'}}{\partial \hat{\tau}_{E,I}} \frac{d\hat{\tau}_{E,I}}{dp^*} + \frac{\partial NB^{E'}}{\partial \hat{\tau}_I} \frac{d\hat{\tau}_I}{dp^*}, \tag{35}$$

where

$$\begin{aligned}
\frac{\partial NB^{E'}}{\partial p^*} &= (1+a)\left[x(p^* - \hat{\tau}_{E,I}) - x(p^* - \hat{\tau}_I)\right] \\
&\quad +(a+\theta_E+\theta_I)\left[(\hat{\tau}_{E,I} - \beta)\, x'(p^* - \hat{\tau}_{E,I}) - (\hat{\tau}_I - \beta)\, x'(p^* - \hat{\tau}_I)\right], \\
\frac{\partial NB^{E'}}{\partial \hat{\tau}_{E,I}} &= 0, \\
\frac{\partial NB^{E'}}{\partial \hat{\tau}_I} &= (1+a)\, x(p^* - \hat{\tau}_I) \\
&\quad -(a+\theta_E+\theta_I)\left[x(p^* - \hat{\tau}_I) - (\hat{\tau}_I - \beta)\, x'(p^* - \hat{\tau}_I)\right].
\end{aligned}$$

The first term on the right-hand-side of (35) represents the change in $NB^{E'}$ for a given change in p^* keeping $\hat{\tau}_I$ and $\hat{\tau}_{E,I}$ constant. This effect can be decomposed into two effects. The first is a change in producer surplus. The sign of this term will be negative if $\hat{\tau}_{E,I} > \hat{\tau}_I$. An increase in p^* will discourage environmental lobby formation if the producer surplus when they are organized is smaller than that when they are not. The second is a change in pollution distortions. An increase in p^* will encourage environmental lobby formation if the environmental distortions when they are organized is smaller than that when they are not.

The second term on the right-hand-side of (35) represents the change in $NB^{E'}$ due to the change in endogenous pollution tax $\hat{\tau}_{E,I}$ that is caused by the change in p^*. It can be shown that this is equal to zero. The third term on the right-hand-side of (35) represents the change in $NB^{E'}$ due to the change in endogenous pollution tax $\hat{\tau}_I$ that is caused by the change in p^*. This effect can be decomposed into two effects. The first is a change in producer surplus. The sign of this term is positive. A reduction in $\hat{\tau}_I$ increases the producer surplus when only the industry lobby is in place. This will increase the necessary amount of political contributions and hence decrease the environmentalists' incentives to form a lobby. The second is a change in pollution distortions. The sign of this term is negative. A reduction in $\hat{\tau}_I$ increases the environmental loss when only the industry lobby is in place. This will decrease the amount of political contributions and hence increase the environmentalists' incentives to form the lobby.

The total effect is ambiguous and depends on the relative magnitude of those effects. However, under the production and preference structure assumed above, the sign of $dNB^{E'}/dp^*$ can be determined. The following lemma deals with this issue.

Lemma 6 : The net benefit from environmental lobby formation in the presence of an industry lobby is increasing in the world price of the polluting good x. That is, $dNB^{E'}/dp^* > 0$.

Proof: Differentiating (34) with respect to p^* gives

$$\frac{dNB^{E'}}{dp^*} = \frac{K(a+1)^2\theta_E^2(p^*-\eta)}{2(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)} > 0,$$

that is, the net benefit from environmental lobby formation in the presence of an industry lobby is an increasing function of the world price of the polluting good. Q.E.D.

As before, let $p^* = \bar{p}^{E'}$ solves the equation, $NB^{E'}(p^*) = F$. Then, the following proposition can be obtained.

Proposition 9 : Suppose that an industry lobby is in place in the small country exporting the polluting good to the large country. If unilateral tariff reductions by the large

country raise p^* above $p^* = \bar{p}^{E'}$, then the small country's environmental policy will be strengthened from $\hat{\tau}_I$ to $\hat{\tau}_{E,I}$.

If the unilateral tariff reductions by the large foreign country raise p^* above $p^* = \bar{p}^{E'}$, then the home environmentalists will be organized. They will compete effectively with the existing industry lobby to oppose a too weak environmental policy and lobby for a more stringent environmental policy. As a result, the equilibrium environmental policy will move toward the efficient Pigovian tax from $\hat{\tau}_I$ to $\hat{\tau}_{E,I}$.

3.4.4 Industrialist's Incentives in the Presence of an Environmental Lobby

Suppose in turn that initially an environmental lobby is in place while industry lobby is not. That is, $NB^{I'} < F$ for initial p^*. Using (12)–(15), $NB^{I'}$ can be written as

$$\begin{aligned} NB^{I'} &= (1+a)\left[\pi(p^* - \hat{\tau}_{E,I}) - \pi(p^* - \hat{\tau}_E)\right] \\ &\quad + (a + \theta_E + \theta_I)\left[(\hat{\tau}_{E,I} - \beta)\, x(p^* - \hat{\tau}_{E,I}) - (\hat{\tau}_E - \beta)\, x(p^* - \hat{\tau}_E)\right] \end{aligned}$$

As before, consider initially how the net benefit from industry lobby formation in the presence of environmental lobby will be affected by θ_I, θ_E, a, η. Under the production and preference structure assumed above, the net benefit function for industrialists in the presence of an environmental lobby can be written as

$$NB^{I'} = \frac{K[a(1-\theta_I) + \theta_E]^2 \,(p^* - \eta)^2}{4(a + 2\theta_E)^2(a + 2\theta_I - 1 + 2\theta_E)}. \tag{36}$$

Thus, the following proposition with regard to the effect of θ_I, θ_E, a, η on $NB^{I'}$ can be obtained.

Proposition 10 : Suppose that industrialists and environmentalists comprise a sufficiently small fraction of the total population. Then, the net benefit from lobby formation for industrialists in the presence of environmental lobby $NB^{I'}$ is (1) decreasing in the

number of industrialists themselves θ_I, (2) decreasing in the number of environmentalists θ_E, (3) decreasing in the government's weight on aggregate social welfare a, and (4) decreasing in the marginal damage from pollution η.

Proof: See Appendix E.

As in the case of the environmentalists, most of the results here are qualitatively the same as in the case where no lobby is formed initially. The only exception is (2), that is, the effect of increasing the number of environmentalists. In the previous case, increasing the number of environmentalists has no impact on industrialist's behavior. On the other hand, for a pre-existing environmental lobby, increasing the number of environmentalists can affect the net benefit from industry lobby formation. In particular, if both industrialists and environmentalists comprise a sufficiently small fraction of the total pollution, increasing the number of environmentalists reduces the industrialist's net benefit from lobby formation. An intuition is as follows. Increasing the number of environmentalists increases their gain from the initial $\hat{\tau}_E$ relative to $\hat{\tau}_{E,I}$. This will increase the amount of political contributions that the industrialists have to pay in order to obtain protections and hence decrease the industrialists' incentives to form a lobby.

Now the question of how an increase in p^* brought about by further tariff reduction affects the net benefit from industry lobby formation is examined. To do so, differentiate $NB^{I'}$ with respect to p^* to obtain

$$\frac{dNB^{I'}}{dp^*} = \frac{\partial NB^{I'}}{\partial p^*} + \frac{\partial NB^{I'}}{\partial \hat{\tau}_{E,I}} \frac{d\hat{\tau}_{E,I}}{dp^*} + \frac{\partial NB^{I'}}{\partial \hat{\tau}_E} \frac{d\hat{\tau}_E}{dp^*}, \tag{37}$$

where

$$\begin{aligned}
\frac{\partial NB^{I'}}{\partial p^*} &= (1+a)\left[x(p^*-\hat{\tau}_{E,I})-x(p^*-\hat{\tau}_E)\right] \\
&\quad +(a+\theta_E+\theta_I)\left[(\hat{\tau}_{E,I}-\beta)\,x'(p^*-\hat{\tau}_{E,I})-(\hat{\tau}_E-\beta)\,x'(p^*-\hat{\tau}_E)\right] \\
\frac{\partial NB^{I'}}{\partial \hat{\tau}_{E,I}} &= 0, \\
\frac{\partial NB^{I'}}{\partial \hat{\tau}_E} &= (1+a)\,x(p^*-\hat{\tau}_E) \\
&\quad -(a+\theta_E+\theta_I)\left[x(p^*-\hat{\tau}_E)-(\hat{\tau}_E-\beta)\,x'(p^*-\hat{\tau}_E)\right].
\end{aligned}$$

The first term on the right-hand-side of (37) represents the change in $NB^{I'}$ for a given change in p^* keeping $\hat{\tau}_{E,I}$ and $\hat{\tau}_E$ constant. This effect can be decomposed into two contributing effects. The first is a change in producer surplus. The sign of this term will be positive if $\hat{\tau}_{E,I} < \hat{\tau}_E$. An increase in p^* will encourage industry lobby formation if the producer surplus when they are organized is greater than when they are not. The second is a change in pollution distortions. The sign of this term will be negative if $\hat{\tau}_{E,I} < \hat{\tau}_E$. An increase in p^* will discourage industry lobby formation if the environmental loss when they are organized is greater than that when they are not.

The second term on the right-hand-side of (37) represents the change in $NB^{I'}$ due to the change in endogenous pollution tax $\hat{\tau}_{E,I}$ that is caused by the change in p^*. It can be shown that this is equal to zero. The third term on the right-hand-side of (37) represents the change in $NB^{I'}$ due to the change in endogenous pollution tax $\hat{\tau}_E$ that is caused by the change in p^*. This effect can be decomposed into two effects. The first is a change in producer surplus. The sign of this term is positive. An increase in $\hat{\tau}_E$ reduces the producer surplus when only environmental lobby is in place. This will reduce the necessary amount of political contributions and hence increase the industrialists' incentives to form the lobby. The second is a change in pollution distortions. The sign of this term is negative. An increase in $\hat{\tau}_E$ increases the environmental gain when only an environmental lobby is in place. This will increase the amount of political contributions and hence decrease the industrialists' incentives to form the lobby.

The total effect depends on the relative magnitude of those effects. Again, under the production and preference structures assumed above, the following lemma with regard to the sign of $dNB^{I'}/dp^*$ can be obtained.

Lemma 7 : The net benefit from industry lobby formation in the presence of an environmental lobby is increasing in the world price of the polluting good x. That is, $dNB^{I'}/dp^* > 0$.

Proof: Differentiating (36) with respect to p^* to obtain

$$\frac{dNB^{I'}}{dp^*} = \frac{K[a(1-\theta_I)+\theta_E]^2(p^*-\eta)}{2(a+2\theta_E)^2(a+2\theta_I-1+2\theta_E)} > 0,$$

that is, the net benefit from industry lobby formation in the presence of an environmental lobby is an increasing function of the world price of the polluting good. Q.E.D.

As before, let $p^* = \bar{p}^{I'}$ solve the equation, $NB^{I'}(p^*) = F$. Then, the following proposition can be obtained.

Proposition 11 : Suppose that an environmental lobby is in place in the small country exporting the polluting good to the large country. If the unilateral tariff reductions by the large country raise p^* above $p^* = \bar{p}^{I'}$, then the small country's environmental policy will be weakened from $\hat{\tau}_E$ to $\hat{\tau}_{E,I}$.

If the unilateral tariff reductions by the large foreign country raise p^* above $p^* = \bar{p}^{I'}$, then the home industrialists will be organized. They will compete effectively with the existing environmental lobby to oppose a too strict environmental policy and lobby for a less stringent environmental policy. As a result, the equilibrium environmental policy will be weakened from $\hat{\tau}_E$ to $\hat{\tau}_{E,I}$, but move toward the efficient Pigovian tax.

3.5 Numerical Example

The preceding section examined how unilateral tariff reductions by the large foreign country will affect the net benefit from lobby formation in the home country. There, to obtain clear

analytical results, two simplifying assumptions were made. The first was that the supply function of the polluting good x takes a linear form. The second was that all individual types equally care about the environment. With these simplifying assumptions, section 3.4.1 considered the case in which no lobby is formed initially and characterized conditions under which an industry lobby is formed first. On the other hand, sections 3.4.2 and 3.4.3 considered the case in which only one lobby was formed initially and showed that unilateral tariff reductions will generate formation of the other lobby group. This section examines the connection between the two. That is, it asks the question about which lobby is formed first in response to unilateral trade liberalization and how a further reduction of trade barriers affects the other group's incentives to form a lobby. However, obtaining an analytical result turns out to be difficult because of the complexity of the model. Instead, numerical simulations using specific functional forms and parameters enable to obtain some sense of this question. The following discusses the findings.

First, with regard to the production structure, lets continue to assume the Cobb-Douglas production function for the polluting good x. In this case, the reward to the specific factor K can be derived as

$$\pi = K\left(\alpha^{\frac{\alpha}{1-\alpha}} - \alpha^{\frac{1}{1-\alpha}}\right)(p^* - \tau)^{\frac{1}{1-\alpha}}$$

and the supply of x as

$$x = K\alpha^{\frac{\alpha}{1-\alpha}}(p^* - \tau)^{\frac{\alpha}{1-\alpha}}.$$

To make comparisons of net benefits easier, continue to assume that both environmentalists and industrialists face exactly the same amount of fixed costs of lobby formation. Also assume that the numbers of environmentalists and industrialists are the same, that is, $\theta_E = \theta_I$. In addition, then relax the previous two simplifying assumptions by choosing various $\alpha \in (0,1)$ and $\eta_E \geq \eta_I \geq \eta_W$. Other parameters adopted here are $a = 10$, $\theta_E = \theta_I = 0.25$, $K = 10$, and $F = 1$.

The situation in which $\alpha = 1/2$ and $\eta_E = \eta_I = \eta_W = 0.5$ serves as the benchmark case.

Figure 6 illustrates the results. Note that TNB^j in the figure represents the total net benefit of lobby j, that is, $TNB^j = NB^j - F$. As shown in the figure, the curve that crosses the horizontal axis first is TNB^I at $p = 3.09$. Thus, $\bar{p}^I = 3.09$. Suppose that initially $p^* < \bar{p}^I$. If unilateral trade liberalizations raise p^* above $\bar{p}^I$, then an industry lobby is formed in the home country. Organized industry lobby demands for less stringent environmental policy so that the political equilibrium environmental policy will be weakened from $\hat{\tau}$ to $\hat{\tau}_I$. In the presence of the industry lobby, the net benefit to environmentalists from forming an organized lobby will shift from TNB^E that crosses the horizontal axis at $p = 8.70$ to $TNB^{E'}$ that crosses the horizontal axis at $p = 7.40$. Thus, $\bar{p}^E = 8.70$ and $\bar{p}^{E'} = 7.40$. If further trade liberalization raises p^* above $\bar{p}^{E'}$, then an environmental lobby is formed in the home country. The organized environmental lobby competes with the existing industry lobby to demand for more stringent environmental policy. The political equilibrium environmental policy will move from $\hat{\tau}_I$ to $\hat{\tau}_{E,I}$. Notice that in the presence of an environmental lobby the net benefit to industrialists from forming an organized lobby will shift from TNB^I to $TNB^{I'}$ that crosses the horizontal axis at $p = 3.21$. However, for p^* above $\bar{p}^E$, $TNB^{I'} > 0$ so that the industry lobby has no incentive to be disorganized.

Suppose that the share of labor decreases from $\alpha = 1/2$ to $\alpha = 1/3$,[42] but still $\eta_E = \eta_I = \eta_W = 0.5$. Figure 7 describes the situation. Notice that in this case $\bar{p}^I = 2.47$ and $\bar{p}^{I'} = 2.66$ for industrialists, while $\bar{p}^E = 10.06$ and $\bar{p}^{E'} = 7.33$ for environmentalists. That is, industrialists now have more incentives to become organized, while environmentalists have less. Notice that the net benefit function for environmentalists becomes flatter so that their response to changes in p^* is much smaller. Therefore, for a smaller share of labor relative to capital, we are more likely to see the emergence of the industry lobby first in response to the unilateral tariff reductions by the foreign country.

Suppose, on the contrary, that the share of labor increases to $\alpha = 2/3$, but still $\eta_E = \eta_I = \eta_W = 0.5$. Figure 8 illustrates the situation. Now, in this case, $\bar{p}^I = 3.00$ and $\bar{p}^{I'} = 3.05$ for industrialists, while $\bar{p}^E = 5.81$ and $\bar{p}^{E'} = 5.36$ for environmentalists. That is, compared to the case of $\alpha = 1/3$, environmentalists now have more incentives to get organized, while

[42] Or, equivalently, the share of capital increases from $1 - \alpha = 1/2$ to $1 - \alpha = 2/3$.

industrialists have less. The net benefit function for environmentalists becomes more elastic so that their response to changes in p^* is much larger. Thus, for a larger share of labor relative to capital, the likelihood that the environmental lobby emerges first in response to the unilateral tariff reductions by the foreign country will be higher.

Finally, suppose that $\eta_E > \eta_I > \eta_W$, but still $\alpha = 1/2$. In particular, suppose that $\eta_E = 1$, $\eta_I = 0.5$, and $\eta_W = 0$. Figure 9 describes the situation. In this case, $\bar{p}^I = 3.02$ and $\bar{p}^{I'} = 3.14$ for industrialists, while $\bar{p}^E = 7.95$ and $\bar{p}^{E'} = 6.75$ for environmentalists. Compared to the benchmark case of $\alpha = 1/2$, one can find that both groups have more incentives to become organized. Thus, if environmentalists become more careful about the environment, both groups will have higher incentives to become organized but we still see the emergence of the industry lobby first in response to the unilateral tariff reductions by the foreign country.

The above results suggest the following. Unilateral trade liberalizations by the large foreign country that lead to an increase in the world price of the polluting good will first generate the industry lobby in the home country. Further reductions of trade barriers will cause the environmental lobby formation in the presence of industry lobby in the home country. During the process of trade liberalization, a home country's environmental policy first becomes too weak, but finally moves toward the efficient Pigovian tax. Notice that above result still holds for other reasonable sets of parameters. Moreover, the result that an industry lobby is formed first rather than environmental lobby can hold unless industrialists comprise an extremely large fraction in total population. That is, a higher θ_I (at least 75% in the total population) is needed in order for industrialists to have smaller incentives to become organized and also higher θ_E (at least over 25%) for environmentalists to have higher incentives to form the lobby.[43] This situation not only seems to be unrealistic, but also violates the assumption that $\theta_E + \theta_I < 1$.

[43] See propositions 5 and 6 for intuition of this argument.

3.6 Concluding Remarks

This essay studied how one country's decision to liberalize trade will have an impact on the political-economic structure that chooses the environmental policy in other country. To investigate the question, a political economy model was constructed in which the formation of lobby groups and environmental policy are endogenously determined. The results obtained are summarized as follows.

First, it was shown that a unilateral tariff reduction by a large country importing a dirty good will generate an industry lobby group and hence reduce the stringency of environmental regulation in a small country exporting that good if both industrialists and environmentalists comprise a sufficiently small fraction of the total pollution in the small country. Second, it was shown that in the presence of either lobby group the unilateral tariff reduction will encourage the formation of the other lobby group in the small country. As a result, the equilibrium environmental policy will move toward the efficient Pigovian tax. Finally, numerical simulations show that for a reasonable set of parameters the unilateral trade liberalization will first generate the industry lobby and further reductions of trade barriers will cause the formation of the environmental lobby in the small country. The predictions in this essay support the political forces behind the inverse U-shaped relationship between trade, growth, and the environment known as the Environmental Kuznets Curve.

This essay focused on unilateral tariff reductions by the foreign country. One possible extension is to apply the model to study the recent debate on the multilateral environmental agreements (MEAs) such as the Kyoto protocols. There is a concern that whether the current participants to the Kyoto protocols should sign the agreement without persuading the non-participants to join the agreement. The question is whether it is possible that the participant's decision to abate pollution can induce non-participants to adopt more stringent environmental regulations. The analysis of such issue would be a fruitful area for future research.

Figure 5: Net Benefit from Lobby Formation

when No Lobby Formed Initially

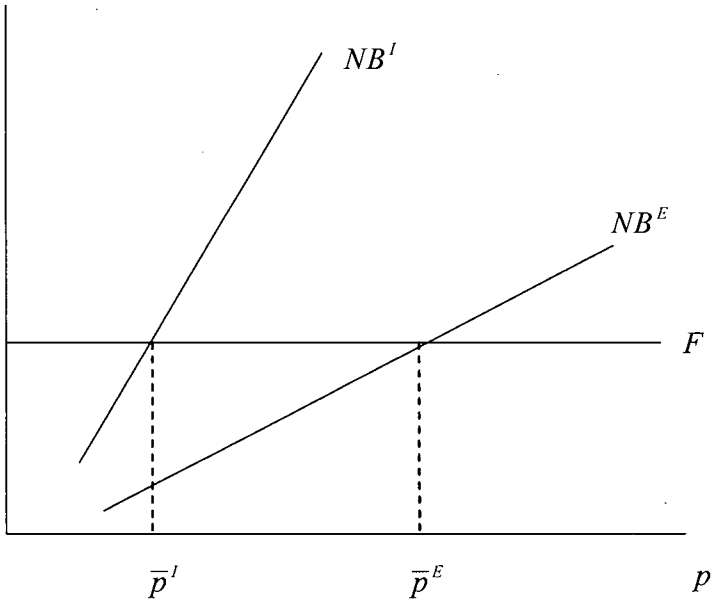


Figure 6: Net Benefit from Lobby Formation

in Response to Unilateral Tariff Reductions (1)

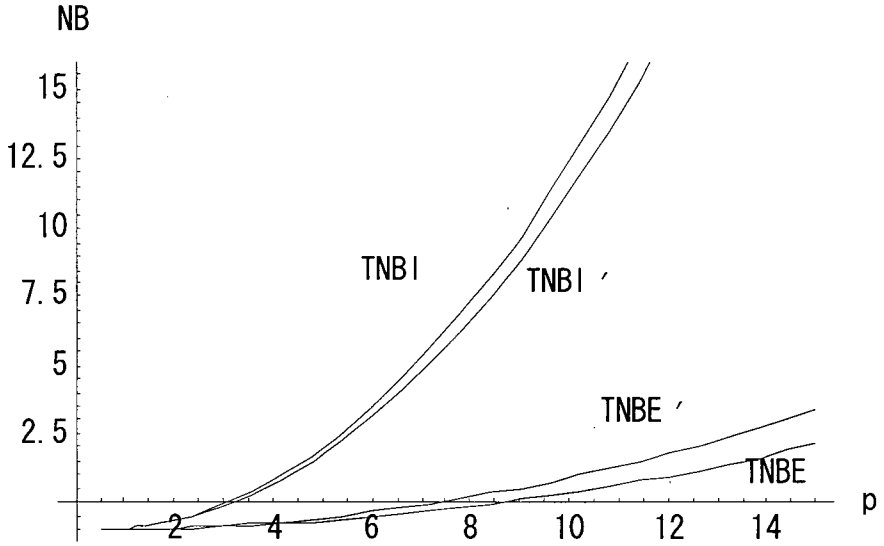


Figure 7: Net Benefit from Lobby Formation

in Response to Unilateral Tariff Reductions (2)

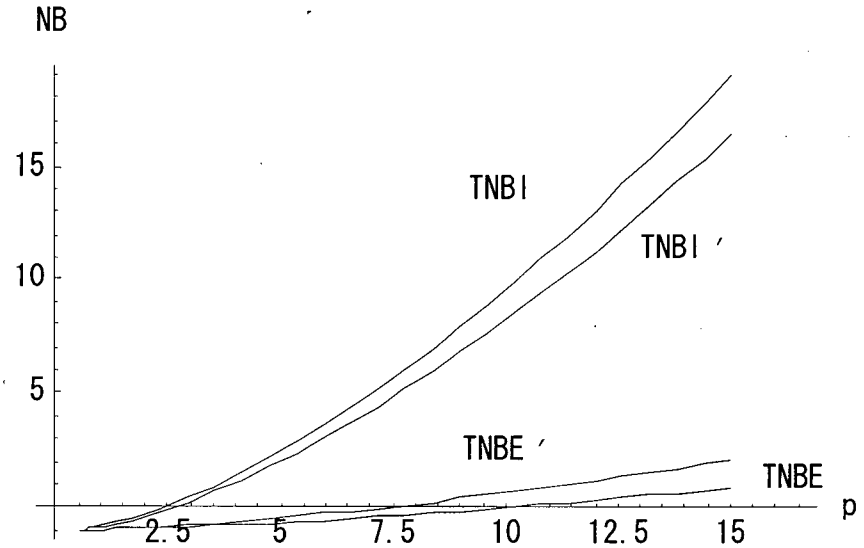


Figure 8: Net Benefit from Lobby Formation

in Response to Unilateral Tariff Reductions (3)

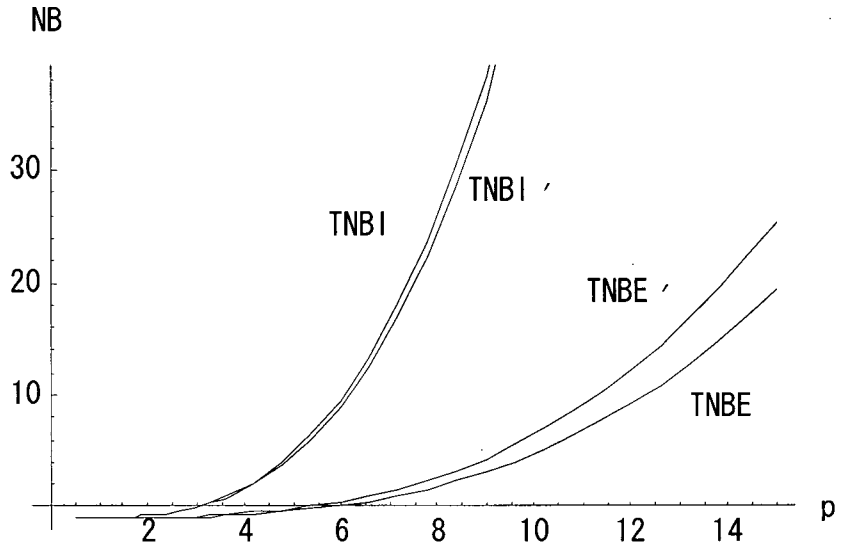
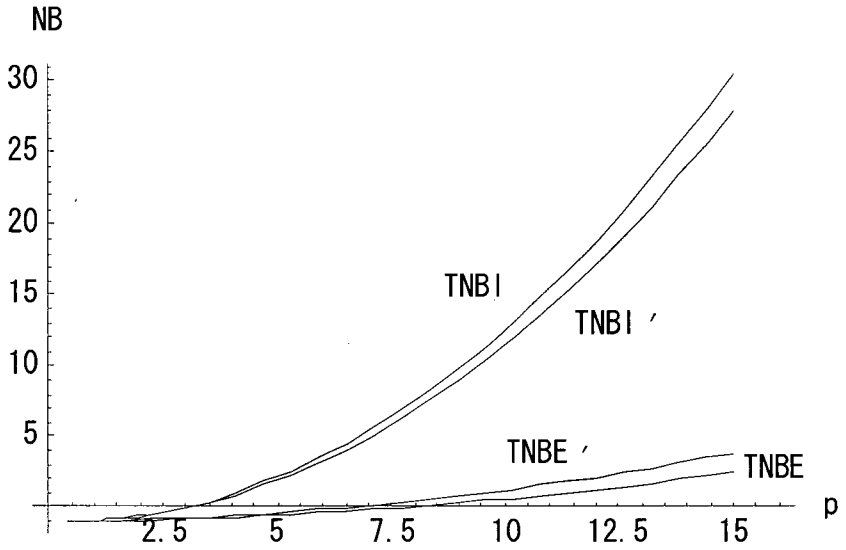


Figure 9: Net Benefit from Lobby Formation

in Response to Unilateral Tariff Reductions (4)



Chapter 4

Welfare-improving Reforms of Environmental Policy in a Large Open Economy

4.1 Introduction

As global warming grows into a serious concern, governments in both developed and developing countries are now under pressure to use various forms of environmental regulations such as an environmental tax or standard to meet national and international environmental objectives. Those taxes and standards can affect international trade when they are imposed on internationally-traded commodities. One important aspect is that when a country is large enough to affect the world market, introducing such regulations is often accompanied by changes in the terms of trade. It is natural that they should be taken into account in evaluating possible costs and benefits that the country obtains from the implementation of such policies.

The purpose of this essay is to investigate how a reform of environmental policy affects the amount of pollution and hence a country's welfare when the reform has an impact on the terms of trade. Reforms of both tax and standards are considered to examine how those reforms have different abilities to abate pollution distortions. The case in which there are multiple as well as single pollutants is also considered and how a reform of one pollutant affects the other remaining pollutants examined.

First, it will be shown that in the single pollutant case the reforms of a pollution tax and a standard that can improve the small country's welfare need not improve the large country's one. In particular, an introduction of a pollution tax improves the terms of trade for the net exporter of the polluting good and deteriorates that for the net importer of that good.

Thus, the pollution tax reform can improve the welfare for a net exporter of the polluting good. For a net importer of the polluting good, the welfare effect depends on the relative magnitude between terms of trade loss and the environmental gain.

The problem becomes complicated if there is an additional pollutant in the economy. It will be shown that the reforms of a pollution tax and a standard that corrects one pollutant will have a spillover effect on the other pollutant regulated by a tax but not on a pollutant regulated by a standard. If pollutants are substitutes of each other, the reform always has a harmful spillover effect on the other pollutant regulated by a pollution tax.

Several studies, including Markusen (1975) and Krutilla (1991), examine optimal environmental policies in an open economy. These studies characterize the second-best optimal environmental policies in the presence of trade distortions. For studies examining the piecemeal policy reforms, Copeland (1994) examines welfare effects of trade and environmental policy reforms in a small open economy. He shows that the proportional reduction of all tariffs and the proportional reduction of all pollution distortions improve the small country's welfare provided that all industries which are subject to trade protections tend to be heavy polluters. Beghin et al. (1997) include consumption-generated pollution and the firm's abatement activity in the model to study the issue. Turunen-Red and Woodland (2002) derive different formulas for welfare-improving policy reforms.

This essay differs from the previous studies in several ways. First, in contrast to Markusen (1975) and Krutilla (1991), it examines piecemeal reforms of environmental policy rather than characterizing the second-best optimal environmental policy. Second, in contrast to Copeland (1994), Beghin et al. (1997), and Turunen-Red and Woodland (2002), it focuses on a large country case rather than a small country case and rather than studying proportional reforms it examines selected policy reforms in which a policymaker seeks to correct one type of pollutant while maintaining other pollution policies as fixed.

The essay is organized as follows. The next section sets up a model and derives an equation that will be used in assessing the welfare impact of policy reforms. Welfare impacts of environmental policy reforms will be examined in section 4.3, which starts from the single pollutant case and then moves on to the multiple pollutants case. The final section concludes

the essay.

4.2 The Model

4.2.1 Structure of the Economy

This section sets up a model of international trade with environmental externalities that will be used throughout the analysis. The model is based on a framework developed by Copeland (1994). Consider a large open economy that produces two goods; a numeraire good and a non-numeraire good. Neither tax nor subsidy (such as a tariff or other domestic tax/subsidy) is imposed on either goods so that the domestic (as well as the world) price of the numeraire is set to one and that of the non-numeraire is denoted by p. Production of goods generates two types of pollutants that negatively affect consumer's utility.[44] One pollutant z^1 is regulated by pollution tax τ^1, while the other pollutant z^2 is regulated by pollution standard. The technology set is assumed to be convex and represented by T.

There are many consumers in the economy who share identical preferences over consumption of the two goods and the environmental damage. The representative consumer's preference can be represented by a utility function of $u = c_0 + u(c) - h(z)$, where c_0 and c denote consumptions of numeraire and non-numeraire goods, respectively, and $z = (z^1, z^2)$. The function h represents the environmental damage and depends positively on z. The cost minimizing behavior for a consumer gives the following expenditure function.

$$e(1, p, z, u) = u - s(p) + h(z),$$

where $s(p) = u\left[c(p)\right] - pc(p)$. Note that $c(\cdot)$ is a compensated demand for the non-numeraire good as a function of its domestic (and world) price and is an inverse of $u'(\cdot)$. Application of the envelope theorem recovers the compensated demand for the non-numeraire good as $\partial e/\partial p = e_p = c$.

[44] Thus, for simplicity, assume that pollutants do not affect a firm's productivity. For studies dealing with this issue, see, for example, Baumol and Oates (1988), and Copeland and Taylor (1999).

The production side of the economy can be described by the GNP function,[45]

$$g(1,p,\tau^1,z^2) = \max_{\{y_0,y,z^1,z^2\}} \{y_0 + py - \tau^1 z^1 \mid (y_0,y,z^1,z^2) \in T\},$$

where y_0 and y denote productions of numeraire and non-numeraire goods, respectively. Again, using the envelope theorem gives the output of the non-numeraire good as $\partial g/\partial p = g_p = y$.

Equilibrium of the large open economy can be written by the following set of equations.

$$e(1,p,z,u) = g(1,p,\tau^1,z^2) + \tau^1 z^1, \tag{38}$$

$$z^1 = -g_{\tau^1}(1,p,\tau^1,z^2), \tag{39}$$

$$m = x^*(1,p), \tag{40}$$

$$m = e_p(1,p,z,u) - g_p(1,p,\tau^1,z^2), \tag{41}$$

where $g_{\tau^1} = \partial g/\partial \tau^1$. Equation (38) states that the country's expenditure equals the net output plus the tax revenue. This represents the country's budget constraint. It is assumed that revenues from the pollution tax are uniformly distributed to consumers. Equation (39) recovers the pollutant z^1 from the GNP function. Equation (40) states that the home import of the non-numeraire good equals the rest of the world's exports. Equation (41) defines the net import of the non-numeraire good as a difference between its demand and supply. Thus, equations (38)-(41) define the system of 4 equations with 4 unknowns; u, p, m, z^1.

4.2.2 Deriving the Welfare Equation

To examine how a reform of environmental policy affects the country's welfare, this section derives an equation that links a change in welfare to changes in policy instruments.

To do so, first, totally differentiate (38) and use (39) and (41) to obtain

$$du = -mdp - (e_{z^1} - \tau^1)dz^1 - (e_{z^2} - g_{z^2})dz^2, \tag{42}$$

[45] With regard to the properties of the GNP functions, see Dixit and Norman (1980), and Woodland (1982).

where $e_{z^j} = \partial e/\partial z^j$ and $g_{z^2} = \partial g/\partial z^2$.[46] Equation (42) states that the country's welfare can be affected by three sources of changes. The first is a terms of trade change. This is represented by the first term on the right-hand-side. An increase in the world price of the non-numeraire good p will increase (decrease) the large country's welfare, if the country is a net exporter (importer) of that good, that is, $m < (>) 0$.

The second is a distortion from the pollution tax. This is represented by the second term on the right-hand-side of (42). An increase in pollutant z^1 will decrease the country's welfare if e_{z^1} exceeds the tax rate τ^1. Note that the term e_{z^1} represents how a change in pollutant z^1 affects the country's expenditure. The sign of e_{z^1} is positive, indicating that increased pollutant z^1 can be damaging in that it raises the country's expenditure. Thus, e_{z^1} can be interpreted as the marginal damage from pollutant z^1. The same interpretations can be applied for e_{z^2}. That is, the third term on the right-hand-side represents a distortion from the pollution standard imposed on pollutant z^2.

Note that equation (42) includes changes in both endogenous variables (dp, dz^1) and exogenous policy variable dz^2. To examine piecemeal policy reforms, changes in those endogenous variables need to be expressed as changes in policy variables only $(d\tau^1, dz^2)$. To do so, first totally differentiate (39) to obtain,

$$dz^1 = -g_{\tau p}dp - g_{\tau\tau}d\tau^1 - g_{\tau z}dz^2, \tag{43}$$

where $g_{XY} = \partial g/(\partial Y \partial X)$.

Next, totally differentiate (40) and (41) to obtain

$$dm = x_p^* dp, \tag{44}$$

$$dm = m_p dp - g_{p\tau}d\tau^1 - g_{pz}dz^2, \tag{45}$$

where $x_p^* = \partial x/\partial p > 0$ and $m_p = e_{pp} - g_{pp}$.[47] Note that $m_p < 0$ from the concavity of e and convexity of g with respect to p.

[46] Note that $\partial e/\partial u = 1$ in this specification of preference.

[47] Again, in this specification of preference, $e_{pz^1} = e_{pz^2} = e_{pu} = 0$.

Now, substituting (44) into (45) gives

$$Sdp - g_{p\tau}d\tau^1 - g_{pz}dz^2 = 0,$$

or

$$dp = S^{-1}g_{p\tau}d\tau^1 + S^{-1}g_{pz}dz^2, \tag{46}$$

where $S = m_p - x_p^* < 0$. Finally, substituting (46) into (43) gives

$$dz^1 = -\left(g_{\tau\tau} + g_{\tau p}S^{-1}g_{p\tau}\right)d\tau^1 - \left(g_{\tau z} + g_{\tau p}S^{-1}g_{pz}\right)dz^2. \tag{47}$$

Equations (46) and (47) express changes in the terms of trade and the pollutant z^1 as functions of changes in policy variables (τ^1, z^2), respectively. Using those equations together with the welfare equation (42), the next section will investigate the welfare effect of environmental policy reforms.

4.3 Welfare Effect of Environmental Policy Reforms

This section examines the welfare effect of environmental policy reforms. First, consider the case in which there is only one pollutant in the economy and it is regulated by either a pollution tax or a pollution standard. Then, add one more pollutant in the economy and examine how a reform of one pollutant affects the country's welfare through its impact on the remaining pollutant.

4.3.1 Single Pollutant Case

4.3.1.1 Pollution Tax Reform

Suppose that there is only one pollutant in the economy and that it is regulated by the pollution tax. In this case, equation (42) can be re-written[48]

$$du = -mdp - (e_z - \tau)dz.$$

Consider a pollution tax reform $d\tau > 0$. That is,

$$\frac{du}{d\tau} = -m\frac{dp}{d\tau} - (e_z - \tau)\frac{dz}{d\tau}. \tag{48}$$

Note that from (46) and (47)

$$\frac{dp}{d\tau} = S^{-1}g_{p\tau}, \tag{49}$$

$$\frac{dz}{d\tau} = -\left(g_{\tau\tau} + g_{\tau p}S^{-1}g_{p\tau}\right). \tag{50}$$

Substituting (49) and (50) into (48) gives

$$\frac{du}{d\tau} = -mS^{-1}g_{p\tau} + (e_z - \tau)\left(g_{\tau\tau} + g_{\tau p}S^{-1}g_{p\tau}\right), \tag{51}$$

Equation (51) represents how a reform of a pollution tax $d\tau$ affects the large country's welfare.

Now examine the welfare effect of a pollution tax reform. First, as a benchmark, consider a small country case in which there is no terms of trade effect. In this case, (51) reduces to

$$\frac{du}{d\tau} = (e_z - \tau)g_{\tau\tau} = -(e_z - \tau)\frac{\partial z}{\partial \tau},$$

[48]Note that the obvious superscript that was used to distinguish two types of pollutants is omitted.

which gives

$$\left.\frac{du}{d\tau}\right|_{\tau=0} = -e_z \frac{\partial z}{\partial \tau} > 0,$$

where the last inequality comes from the property of the GNP function that g is convex in τ. Thus, this confirms the earlier results by Copeland (1994) that an introduction of a pollution tax always improves the small country's welfare by correcting the existing pollution distortions.

Now, turn to the large country case and consider the introduction of a pollution tax. That is, from (51),

$$\left.\frac{du}{d\tau}\right|_{\tau=0} = -mS^{-1}g_{p\tau} + e_z\left(g_{\tau\tau} + g_{\tau p}S^{-1}g_{p\tau}\right). \tag{52}$$

The first term on right-hand-side of (52) represents the terms of trade effect associated with a pollution tax reform. The sign of this term depends on how the reform affects the net import demand for the non-numeraire good. The second term represents the effects on pollution distortions. The first term in the parenthesis represents the direct effect, while the second represents the terms of trade effect. As in the small country case, the sign of the direct effect is positive from the property of the GNP function. On the other hand, the sign of the term of trade effect is always negative because of $S < 0$ and the continuity of g with respect to p and τ. To characterize conditions for welfare-improvement, define the following.

Definition : A non-numeraire good industry is pollution-intensive if

$$\frac{\partial z}{\partial p} = -g_{\tau p} = -g_{p\tau} = -\frac{\partial y}{\partial \tau} > 0.$$

The above definition implies that the non-numeraire good industry is pollution-intensive, if an expansion of the industry caused by an increase in its domestic (and world) price will generate more pollution, or equivalently, if an increase in the pollution tax will contract the industry.

Now, consider again the first term on the right-hand-side of (52). If the non-numeraire good industry is pollution-intensive, then the sign of this term will be positive if the country is a net exporter of this good. That is, an introduction of the pollution tax will contract the

non-numeraire good industry that is pollution-intensive, which results in an increase in its world price. If the country is a net exporter of this good, this will increase its welfare. Thus, the terms of trade effect associated with the pollution tax reform will be positive for a dirty good exporter and negative for its importer.[49]

On the other hand, the sign of the second term in parenthesis on the right-hand-side of (52) is always negative. If the non-numeraire good industry is pollution-intensive, then increasing its world price caused by the pollution tax reform will expand its production. Or, if the numeraire good industry is, in turn, pollution-intensive, then decreasing p caused by the reform will expand the numeraire good industry. In either case, this second-round effect tends to increase pollution.

Thus, the sign of the second term on the right-hand-side of (52) depends on the relative strength of the direct effect ($g_{\tau\tau}$) and the indirect effect ($g_{\tau p}S^{-1}g_{p\tau}$). However, under the assumption that the foreign export supply curve is upward sloping, the indirect terms of trade effect cannot dominate the direct effect. To confirm this, re-write the second term on the right-hand-side of (52) as

$$\begin{aligned} e_z\left(g_{\tau\tau}+g_{\tau p}S^{-1}g_{p\tau}\right) &= e_zS^{-1}\left(Sg_{\tau\tau}+g_{\tau p}^2\right) \\ &= e_zS^{-1}\left[\left(e_{pp}-x_p\right)g_{\tau\tau}-\left(g_{pp}g_{\tau\tau}-g_{\tau p}^2\right)\right]. \end{aligned}$$

Note that $S = e_{pp} - g_{pp} - x_p$ and $g_{\tau p} = g_{p\tau}$. As noted above, $S < 0$ by concavity of e and convexity of g with respect to p, and by the assumption of $x_p > 0$. Note also that the convexity of g with respect to τ together with the above implies that $(e_{pp} - x_p)\, g_{\tau\tau} < 0$ and $g_{pp}g_{\tau\tau} - g_{\tau p}^2 > 0$. Thus, the sign of the term in the square bracket is negative and the sign of the term overall will be positive. This implies that $dz/d\tau < 0$ in (50); an introduction of the pollution tax necessarily decreases the amount of pollution.

The following proposition summarizes the result obtained above.

[49] Consider the opposite case in which the non-numeraire good is a clean good. In this case, an introduction of the pollution tax will expand the non-numeraire good industry and decrease its world price. If the country is a net importer of the clean good (or equivalently a net exporter of the dirty good), the reform will increase its welfare. Therefore, in either case, the terms of trade effect will be positive for a dirty good exporter (or a clean good importer) and negative for its importer.

Proposition 12 : Suppose that the large country produces two goods and a single pollutant. Then, there is always a harmful indirect effect on the pollutant associated with the pollution tax reform that is caused by the terms of trade change. However, this indirect effect cannot dominate the direct effect on the pollutant. Thus, an introduction of a pollution tax can necessarily decrease the amount of pollution.

The above proposition shows that a reform of the pollution tax that improves the terms of trade for the net exporter of the polluting good and deteriorates that for the net importer of that good will necessarily generate a harmful side effect on the environment. However, this side effect cannot dominate the direct effect, and hence the pollution tax reform that introduces a tax on pollutant will decrease pollution. Thus, the reform can improve the welfare for a net exporter of the polluting good. For a net importer of the polluting good, the welfare effect depends on the relative magnitude between terms of trade loss and the environmental gain.

4.3.1.2 Reform of Pollution Standard

Suppose that the single pollutant is regulated by a pollution standard. In this case, equation (42) can be re-written as

$$du = -mdp - (e_z - g_z)dz.$$

Consider a reform of the pollution standard $dz < 0$. That is,

$$\frac{du}{dz} = -m\frac{dp}{dz} - (e_z - g_z). \tag{53}$$

Note that from (47) there is

$$\frac{dp}{dz} = S^{-1}g_{pz}. \tag{54}$$

Substituting (54) into (53) gives

$$\frac{du}{dz} = -mS^{-1}g_{pz} - (e_z - g_z). \tag{55}$$

Equation (55) represents how a reform of the pollution standard dz affects the large country's welfare.

As before, consider first the small country case in which there is no terms of trade effect. In this case, (55) reduces to

$$\frac{du}{dz} = -(e_z - g_z).$$

This, again, confirms the earlier results by Copeland (1994) that tightening up a pollution standard $dz < 0$ will improve the small country's welfare if the marginal damage from pollution exceeds its marginal abatement cost, i.e., $e_z > g_z$.

Now consider the reform of the pollution standard in the large country case. The first term on the right-hand-side of (55) represents the terms of trade effect associated with the reform. The sign of this term will be negative if the country is a net exporter of the pollution-intensive good. That is, tightening up a pollution standard $dz < 0$ will contract the polluting industry and increase its world price. If the country is a net exporter of this good, this will increase its welfare. Therefore, as in the pollution tax reform, the terms of trade effect associated with a reform of pollution standard will positively affect the welfare for a dirty good exporter but negatively for its importer. The second term on right-hand-side of (55) represents the effect on pollution distortions. As in the small country case, the sign of this term will be negative if the marginal damage from pollution e_z exceeds its marginal abatement cost g_z.

The following proposition summarizes the result obtained above.

Proposition 13 : Suppose that the large country produces two goods and a single pollutant. Then, tightening up a pollution standard can improve the welfare for a net exporter of the polluting good if the marginal damage from pollution exceeds its abatement cost. For a net importer of the polluting good, the reform involves negative terms of trade effect. Total welfare effect depends on the relative magnitude between terms of trade loss and the environmental gain.

Note that contrary to the tax reform the reform of standard does not contain any indirect side effect on the pollutant through the terms of trade effect (that is, the second term in

parenthesis on the right-hand-side of (52)).

4.3.2 Multiple Pollutants Case

4.3.2.1 Regulation by Taxes Only

Suppose now that there are two types of pollutants and that both are regulated by pollution taxes. In this case, treating z^1 and τ^1 in the set of equations (38)-(41) as vectors rather than scalars gives an equation analogous to (42).

$$du = -mdp - (e_{z^1} - \tau^1)dz^1 - (e_{z^2} - \tau^2)dz^2,$$

where τ^2 is a tax on pollutant z^2.

Now consider a pollution tax reform that corrects one pollutant, say z^1. In particular, consider an introduction of a pollution tax on z^1. That is,

$$\left.\frac{du}{d\tau^1}\right|_{\tau^1=0} = -m\frac{dp}{d\tau^1} - e_{z^1}\frac{dz^1}{d\tau^1} - (e_{z^2} - \tau^2)\frac{dz^2}{d\tau^1}. \tag{56}$$

From (46) and (47)

$$\frac{dp}{d\tau^1} = S^{-1}g_{p\tau^1}, \tag{57}$$

$$\frac{dz^1}{d\tau^1} = -\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right), \tag{58}$$

$$\frac{dz^2}{d\tau^1} = -\left(g_{\tau^2\tau^1} + g_{\tau^2 p}S^{-1}g_{p\tau^1}\right). \tag{59}$$

Substitute (57)-(59) into (56) to obtain

$$\begin{aligned}\left.\frac{du}{d\tau^1}\right|_{\tau^1=0} = & -mS^{-1}g_{p\tau^1} + e_{z^1}\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right) \\ & +(e_{z^2} - \tau^2)\left(g_{\tau^2\tau^1} + g_{\tau^2 p}S^{-1}g_{p\tau^1}\right).\end{aligned} \tag{60}$$

Thus, comparing (60) with the analogous equation in the single pollutant case (52), one can find that a pollution tax reform on one pollutant has a spillover effect on the other pollutant. This effect can be represented in the last term on the right-hand-side of (60). Thus, the welfare effect of the pollution tax reform depends on the sign of this spillover term. However, if appropriate pollution policy is imposed on the other pollutant, the spillover effect will disappear. That is, if the pollution tax rate on z^2 is equal to its marginal damage, $\tau^2 = e_{z^2}$,

$$\left.\frac{du}{d\tau^1}\right|_{\tau^1=0,\tau^2=e_{z^2}} = -mS^{-1}g_{p\tau^1} + e_{z^1}\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right).$$

That is, it just comes back to the single pollutant case and hence the conditions under which the pollution tax reform $d\tau^1$ improves the large country's welfare are the same as those discussed in proposition 12.

Now suppose that the appropriate pollution policy is not imposed on pollutant z^2. Moreover, suppose that no pollution policy is imposed on z^2, that is, $\tau^2 = 0$. In this case,

$$\begin{aligned}\left.\frac{du}{d\tau^1}\right|_{\tau^1=\tau^2=0} &= -mS^{-1}g_{p\tau^1} + e_{z^1}\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right) \\ &\quad + e_{z^2}\left(g_{\tau^2\tau^1} + g_{\tau^2 p}S^{-1}g_{p\tau^1}\right).\end{aligned} \tag{61}$$

Consider the last term on the right-hand side of (61). As mentioned above, this term represents the spillover effect associated with the reform of pollutant z^1 on the remaining pollutant z^2. The first term in parenthesis $g_{\tau^2\tau^1}$ represents the direct effect. If pollutants 1 and 2 are substitutes of each other, which seems to be plausible in this two pollutant case, then the sign of this term will be negative. That is, the pollution tax reform $d\tau^1$ that aims to collect pollutant z^1 may increase the remaining pollutant z^2 instead, which negatively affects the welfare.

The second term in parenthesis represents the indirect terms of trade effect on z^2. The sign of this term will be also negative. That is, the pollution tax reform will increase the world price of the polluting good. This will expand the pollution-intensive industry and hence increase pollutant z^2, which negatively affects the welfare. Therefore, the reform of

pollution tax $d\tau^1$ has a harmful spillover effect on the remaining pollutant z^2. The result is summarized in the following proposition.

Proposition 14 : Suppose that the large country produces two goods and two pollutants. Suppose also that no pollution regulations are implemented on either pollutant. Then, introducing a pollution tax on one pollutant will have spillover effects on the remaining pollutant. If the two pollutants are substitutes (complements) of each other, the spillover effects involve harmful (beneficial) direct effects and harmful terms of trade effects. Whether the reform improves the large country's welfare depends on the spillover effects as well as the direct terms of trade effect and the effect on the pollutant of interest.

4.3.2.2 Regulation by Standards Only

Suppose, in turn, that both pollutants are regulated only by pollution standards. In this case, treating z^2 as vectors in (38)-(41) results in an equation analogous to (42).

$$du = -mdp - (e_{z^1} - g_{z^1})dz^1 - (e_{z^2} - g_{z^2})dz^2.$$

Now consider a reform of a pollution standard that corrects one pollutant, say z^1. That is,

$$\frac{du}{dz^1} = -m\frac{dp}{dz^1} - (e_{z^1} - g_{z^1}). \tag{62}$$

From (46)

$$\frac{dp}{dz^1} = S^{-1}g_{pz^1}. \tag{63}$$

Substituting (63) into (62) to obtain

$$\frac{du}{dz^1} = -mS^{-1}g_{pz^1} - (e_{z^1} - g_{z^1}). \tag{64}$$

Notice that (64) is essentially the same as the analogous equation in the single pollutant case (55). Contrary to the pollution tax reform discussed in 4.3.2.1, the reform of pollution

standard dz^1 does not involve any spillover effect on the remaining pollutant z^2 that is also regulated by standard. Thus, the conditions for welfare-improvement are the same as those discussed in proposition 13.

Proposition 15 : Suppose that the large country produces two goods and two pollutants. Then, tightening up a pollution standard on one pollutant can improve the welfare for a net exporter of the polluting good if the marginal damage from pollution exceeds its abatement cost. For a net importer of the polluting good, the reform involves negative terms of trade effect so that the total welfare effect depends on the relative magnitude between terms of trade loss and the environmental gain. There is no spillover effect associated with the reform on the other remaining pollutant.

4.3.2.3 Mixed Regime

Finally, consider a mixed regime in which one pollutant is regulated by a tax and the other by a standard. In this case, (42) is the relevant equation. First, consider a pollution tax reform that introduces a pollution tax on z^1. That is,

$$\left.\frac{du}{d\tau^1}\right|_{\tau^1=0} = -m\frac{dp}{d\tau^1} - e_{z^1}\frac{dz^1}{d\tau^1}. \tag{65}$$

From (46) and (47)

$$\frac{dp}{d\tau^1} = S^{-1}g_{p\tau^1}, \tag{66}$$

$$\frac{dz^1}{d\tau^1} = -\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right). \tag{67}$$

Substituting (66) and (67) into (65) to obtain

$$\left.\frac{du}{d\tau^1}\right|_{\tau^1=0} = -mS^{-1}g_{p\tau^1} + e_{z^1}\left(g_{\tau^1\tau^1} + g_{\tau^1 p}S^{-1}g_{p\tau^1}\right). \tag{68}$$

Notice that equation (68) is essentially the same as the analogous equation in the single pollutant case (52). Contrary to the case of pollution taxes only, discussed in 4.3.2.1, the pollution tax reform in this case does not involve any spillover effect on the remaining pollutant that is regulated by standard. Thus, the conditions for welfare-improvement are the same as those discussed in proposition 12.

Proposition 16 : Suppose that the large country produces two goods and two pollutants. Then, an introduction of a pollution tax on one pollutant has no spillover effect on the other pollutant that is regulated by a pollution standard. Thus, the welfare effect of the pollution tax reform is the same as the single pollutant case.

Next consider a reform of the pollution standard $dz^2 < 0$. From (42),

$$\frac{du}{dz^2} = -m\frac{dp}{dz^2} - (e_{z^1} - \tau^1)\frac{dz^1}{dz^2} - (e_{z^2} - g_{z^2}). \tag{69}$$

From (46) and (47),

$$\frac{dp}{dz^2} = S^{-1}g_{pz^2}, \tag{70}$$

$$\frac{dz^1}{dz^2} = -\left(g_{\tau^1 z^2} + g_{\tau^1 p}S^{-1}g_{pz^2}\right). \tag{71}$$

Substituting (70) and (71) into (69) to obtain

$$\frac{du}{dz^2} = -mS^{-1}g_{pz^2} + (e_{z^1} - \tau^1)\left(g_{\tau^1 z^2} + g_{\tau^1 p}S^{-1}g_{pz^2}\right) - (e_{z^2} - g_{z^2}). \tag{72}$$

Thus, comparing (72) with the analogous equation in the case of pollution standards only (62), one can find that a reform of pollution standard has a spillover effect on the remaining pollutant that is regulated by a pollution tax. This effect can be represented in the second term on the right-hand-side of (72). Thus, the welfare effect of the pollution standard reform depends on the sign of this spillover term. However, if appropriate pollution policy is imposed on the other pollutant, the spillover effect will disappear. That is, if the pollution tax rate

on z^1 is equal to its marginal damage, $\tau^1 = e_{z^1}$, then

$$\left.\frac{du}{dz^2}\right|_{\tau^1=e_{z^1}} = -mS^{-1}g_{pz^2} - (e_{z^2} - g_{z^2}).$$

That is, it just comes back to the single pollutant case and hence the conditions under which the pollution standard reform dz^2 improves the large country's welfare are the same as those discussed in proposition 13.

Now suppose that the appropriate pollution policy is not imposed on the pollutant z^1. Moreover, suppose that no pollution policy is imposed on pollutant z^1, that is, $\tau^1 = 0$. In this case,

$$\left.\frac{du}{dz^2}\right|_{\tau^1=0} = -mS^{-1}g_{pz^2} + e_{z^1}\left(g_{\tau^1 z^2} + g_{\tau^1 p}S^{-1}g_{pz^2}\right) - (e_{z^2} - g_{z^2}). \tag{73}$$

Consider the second term on the right-hand side of (73). As mentioned above, this term represents the spillover effect associated with the reform of pollutant z^2 on the remaining pollutant z^1 that is regulated by a tax. The first term in parenthesis $g_{\tau^1\tau^2}$ represents the direct effect. If pollutants 1 and 2 are substitutes of each other, the sign of this term will be positive. That is, the reform of pollution standard dz^2 that tightens up pollutant z^2 may increase the remaining pollutant z^1 instead, which negatively affects the welfare.

The second term in parenthesis represents the indirect terms of trade effect on z^1. The sign of this term will be also positive. That is, the reform of pollution standard reform will increase the world price of the polluting good. This will expand the pollution-intensive industry and hence increase pollutant z^1, which negatively affects the welfare. Therefore, the reform of pollution standard dz^2 has a harmful spillover effect on the remaining pollutant z^1. The result is summarized in the following proposition.

Proposition 17 : Suppose that the large country produces two goods and two pollutants. Suppose also that no pollution regulations are implemented on either pollutant. Then, tightening up a pollution standard on one pollutant will have spillover effects on the remaining pollutant. If two pollutants are substitutes (complements) of each other, the spillover effects involve harmful (beneficial) direct effects and harmful terms of

trade effects. Whether the reform improves the large country's welfare depends on the spillover effects as well as the direct terms of trade effect and the effect on the pollutant of interest.

4.4 Concluding Remarks

This essay investigated how a reform of environmental policy affects the amount of pollution and hence a country's welfare when the reform has an impact on the terms of trade. Reforms of both tax and standard were considered to examine how those reforms have different abilities to abate pollution distortions. It also considered the case in which there are multiple as well as single pollutants and examined how a reform of one pollutant affects the other remaining pollutant. The results obtained can be summarized as follows.

First, in the single pollutant case, the reforms of a pollution tax and a standard that can improve the small country's welfare need not improve the large country's one. In particular, an introduction of a pollution tax improves the terms of trade for the net exporter of the polluting good and deteriorates that for the net importer of that good. Thus, the reform can improve the welfare for a net exporter of the polluting good. For a net importer of the polluting good, the welfare effect depends on the relative magnitude between terms of trade loss and the environmental gain. The problem becomes complicated if there is an additional pollutant in the economy. The reforms of a pollution tax and standard that correct one pollutant were shown to have a spillover effect on the other pollutant regulated by a tax but not on a pollutant regulated by a standard. If pollutants are substitutes of each other, the reform always has a harmful spillover effect on the other pollutant regulated by a pollution tax.

Bibliography

[1] Aidt, Toke S. "Political Internalization of Economic Externalities and Environmental Policy." *Journal of Public Economics* 69, no. 1 (July 1998): 1-16.

[2] Baumol, William J., and Wallace E. Oates. *The Theory of Environmental Policy.* Cambridge: Cambridge University Press, 1988.

[3] Beaton, Stuart P., Gary A. Bishop, Yi Zhang, Lowell L. Ashbaugh, Douglas R. Lawson, and Donald H. Stedman. "On-Road Vehicle Emissions: Regulations, Costs, and Benefits." *Science* 268 (May 1995): 991-993.

[4] Beghin, John, David Roland-Holst, and Dominique Van Der Mensbrugghe. "Trade and Pollution Linkages: Piecemeal Reform and Optimal Intervention." *Canadian Journal of Economics* 30, no. 2 (May 1997): 442-455.

[5] Bernheim, B. Douglas, and Michael D. Whinston. "Menu Auctions, Resource Allocation, and Economic Influence." *Quarterly Journal of Economics* 101, no. 1 (February 1986): 1-32.

[6] Besley, Timothy, and Stephen Coate. "Sources of Inefficiency in a Representative Democracy." *American Economic Review* 88, no. 1 (March 1998): 139-159.

[7] Bommer, Rolf, and Gunther G. Schulze. "Environmental Improvement with Trade Liberalization." *European Journal of Political Economy* 15, no. 4 (November 1999): 639-661.

[8] Brett, Craig, and Michael Keen. "Political Uncertainty and the Earmarking of Environmental Taxes." *Journal of Public Economics* 75, no. 3 (March 2000): 315-340.

[9] Cho, In-Koo, and David M. Kreps. "Signaling Games and Stable Equilibria." *Quarterly Journal of Economics* 102, no. 2 (May 1987): 179-222.

[10] Coate, Stephen, and Stephen Morris. "On the Form of Transfers to Special Interests." *Journal of Political Economy* 103, no. 6 (December 1995): 1210-1235.

[11] Coates, Dennis. "Jobs versus Wilderness Areas: the Role of Campaign Contributions." In *The Political Economy of Environmental Protection: Analysis and Evidence*, ed. Roger D. Congleton, 69-96. Ann Arbor: University of Michigan Press, 1996.

[12] Coninx, Paul. *Vehicle Emissions Testing: Air Care, Dirive Clean, and the Future of Inspection and Maintenance Programs.* Vancouver: The Fraser Institute, 1998.

[13] Copeland, Brian R. "International Trade and the Environment: Policy Reform in a Polluted Small Open Economy." *Journal of Environmental Economics and Management* 26, no.1 (January 1994): 44-65.

[14] Copeland, Brian R., and M. Scott Taylor. "Trade, Spatial Separation, and the Environment." *Journal of International Economics* 47, no. 1 (February 1999): 137-168.

[15] Copeland, Brian R, and M. Scott Taylor. "Trade, Growth and the Environment." *Journal of Economic Literature* 42, no. 1 (March 2004): 7-71.

[16] Cropper, Maureen L., William N. Evans, Stephen J. Berardi, Maria M. Ducla-Soares, and Paul R. Portney. "The Determinants of Pesticide Regulation: A Statistical Analysis of EPA Decision Making." *Journal of Political Economy* 100, no. 1 (February 1992): 175-197.

[17] Damania, Richard, Per G. Fredriksson, and John A. List. "Trade Liberalization, Corruption, and Environmental Policy Formation: Theory and Evidence." *Journal of Environmental Economics and Management* 46, no. 3 (November 2003): 490-512.

[18] Dean, Judith M. "Testing the Impact of Trade Liberalization on the Environment: Theory and Evidence." *Canadian Journal of Economics* 35, no. 4 (November 2002): 819-842.

[19] Dewees, Donald N., and Michael J. Hare. "Economic Analysis of Packaging Waste Reduction." *Canadian Public Policy* 24, no. 4 (December 1998): 453-470.

[20] Dixit, Avinash K., and Victor Norman. *Theory of International Trade.* Cambridge: Cambridge University Press, 1980.

[21] Esty, Daniel C. *Greening the GATT: Trade, Environment, and Future.* Washington, DC: Institute for International Economics, 1994.

[22] Fredriksson, Per G. "The Political Economy of Pollution Taxes in a Small Open Economy." *Journal of Environmental Economics and Management* 33, no. 1 (May 1997): 44-58.

[23] Fredriksson, Per G. "The Political Economy of Trade Liberalization and Environmental Policy." *Southern Economic Journal* 65, no. 3 (January 1999): 513-525.

[24] Grossman, Gene M., and Elhanan Helpman. "Protection for Sale." *American Economic Review* 84, no. 4 (September 1994): 833-850.

[25] Grossman, Gene M., and Alan B. Krueger. "Environmental Impacts of a North American Free Trade Agreement." In *The US-Mexico Free Trade Agreement*, ed. Peter M. Garber, 13-56. Cambridge: MIT Press, 1993.

[26] Hubbart, Thomas N. "Using Inspection and Maintenance Programs to Regulate Vehicle Emissions." *Contemporary Economic Policy* 15, no. 2 (April 1997): 52-62.

[27] Krishna, Pravin, and Devashish Mitra. "Reciprocated Unilateralism in Trade Policy." *Journal of International Economics* 65, no. 2 (March 2005): 461-487.

[28] Krutilla, Kerry. "Environmental Regulation in an Open Economy." *Journal of Environmental Economics and Management* 20, no. 2 (March 1991): 127-142.

[29] Markusen, James R. "International Externalities and Optimal Tax Structures." *Journal of International Economics* 5, no. 1 (February 1975): 15-29.

[30] Mitra, Devashish. "Endogenous Lobby Formation and Endogenous Protection: A Long-Run Model of Trade Policy Determination." *American Economic Review* 89, no. 5 (December 1999): 1116-1134.

[31] Neary, J. Peter. "Trade Liberalisation and Shadow Prices in the Presence of Tariffs and Quotas." *International Economic Review* 36, no. 3 (August 1995): 531-554.

[32] Rogoff, Kenneth. "Equilibrium Political Budget Cycles." *American Economic Review* 80, no. 1 (March 1990): 21-36.

[33] Schleich, Joachim. "Environmental Quality with Endogenous Domestic and Trade Policies." *European Journal of Political Economy* 15, no. 1 (March 1999): 53-71.

[34] Strum, Daniel M. "Product Standards, Trade Disputes and Protectionism." Discussion Paper, no. 486, Centre for Economic Performance, London School of Economics and Political Science, 2001.

[35] Thompson, Barton H., Jr., "Tragically Difficult: The Obstacles to Governing the Commons." *Environmental Law* 30, no. 2 (Spring 2000): 241-278.

[36] Turunen-Red, Arja H., and Alan D. Woodland. "Unilateral Reforms of Trade and Environmental Policy." In *Economic Theory and International Trade: Essays in Honour of Murray C. Kemp*, ed. Alan D. Woodland, 124-140. Northampton: Edward Elgar, 2002.

[37] Woodland, Alan D. *International Trade and Resource Allocation.* Amsterdam: North-Holland, 1982.

Appendices

Appendix A

This appendix gives the proof of proposition 1 in chapter 2. First, given equilibrium strategies for each type of incumbent, the set of beliefs along the equilibrium paths are given by

$$\hat{\rho}(\hat{t}(\eta_L), 0, d) = \frac{\rho}{\rho + (1-\rho)\{1 + [\sigma\eta_H/(1-\sigma)\eta_L]\}},$$
$$\hat{\rho}(\hat{t}(\eta_L), 0, n) = \frac{\rho}{\rho + (1-\rho)\{1 + [\sigma(1-\eta_H)/(1-\sigma)(1-\eta_L)]\}},$$
$$\hat{\rho}(\hat{t}(\eta_H), 0, d) = 1,$$
$$\hat{\rho}(\hat{t}(\eta_H), 0, n) = 1.$$

Define re-election function g as

$$g(\eta_j, \rho) = \eta_j F(\hat{\rho}(\hat{t}(\eta_L), 0, d)) + (1-\eta_j) F(\hat{\rho}(\hat{t}(\eta_L), 0, n)).$$

The function g gives the probability of re-election if an incumbent selects $(\hat{t}(\eta_L), 0)$ when his initial reputation is ρ and the state is η_j $(j = H, L)$. From the citizen's beliefs $\hat{\rho}(\hat{t}(\eta_L), 0, d)$ and $\hat{\rho}(\hat{t}(\eta_L), 0, n)$, the function g can be shown to be (1) continuous in both arguments, (2) increasing in ρ, and (3) decreasing in η_j. Now define ρ^* to be the largest value among $\{\rho_1^*, \rho_2^*, \rho_3^*\}$.

1. ρ_1^* is the smallest value of ρ such that

$$g(\eta_L, \rho) \geq 1 - \frac{\hat{v}(\eta_L) - v_w(\hat{t}(\eta_H), \eta_L)}{\delta \hat{v}(\eta_L)}.$$

2. ρ_2^* is the smallest value of ρ such that

$$g(\eta_L, \rho) \geq \frac{\hat{v}(\eta_L) - v_p(\hat{t}(\eta_L), 0)}{\delta \hat{v}(\eta_L)}.$$

3. ρ_3^* is the smallest value of ρ such that

$$g(\eta_H, \rho) \geq \frac{\hat{v}(\eta_H) - v_p(\hat{t}(\eta_L), 0)}{\delta \hat{v}(\eta_H)}.$$

Existence of such $\rho^* \in (0,1)$ will be guaranteed by assumption 1 together with the properties of g.

Now it is shown that if $\rho > \rho^*$ the pro-welfare incumbent selects $(\hat{t}(\eta_H), 0)$ when η_H and selects $(\hat{t}(\eta_L), 0)$ when η_L, and the pro-industry incumbent always chooses $(\hat{t}(\eta_L), 0)$ when the out of equilibrium belief is given by $\hat{\rho}(t, \tau, h) = 0 \ \forall \ (t, \tau) \neq (\hat{t}(\eta_H), 0), (\hat{t}(\eta_L), 0)$ and $h \in (d, n)$.

First, consider the pro-welfare incumbent's behavior. When η_H, he always prefers selecting $(\hat{t}(\eta_H), 0)$ since this is his one period optimum and gives him re-election with probability of one. When η_L, the pro-welfare incumbent selecting $(\hat{t}(\eta_L), 0)$ will obtain

$$[1 + \delta g(\eta_L, \rho)] \hat{v}(\eta_L).$$

On the other hand, if he chooses $(\hat{t}(\eta_H), 0)$, he will obtain

$$v_w(\hat{t}(\eta_H), \eta_L) + \delta \hat{v}(\eta_L).$$

However, the definition of ρ^* and the property of g imply

$$\begin{aligned} [1 + \delta g(\eta_L, \rho)] \hat{v}(\eta_L) &> [1 + \delta g(\eta_L, \rho^*)] \hat{v}(\eta_L) \\ &\geq v_w(\hat{t}(\eta_H), \eta_L) + \delta \hat{v}(\eta_L). \end{aligned}$$

Note that $\rho > \rho^*$. The first inequality comes from $\rho > \rho^*$ and the property that g is an increasing function of ρ. The second inequality comes from the definition of ρ^* (and also that of ρ_1^*). Therefore, the pro-welfare incumbent selects $(\hat{t}(\eta_L), 0)$ when η_L.

Next, consider the pro-industry incumbent's behavior. By assumption 1, the pro-industry incumbent's choices are either $(\hat{t}(\eta_L), 0)$ or $(\hat{t}(\eta_j), \hat{\tau}(\eta_j))$ when η_j, $j = H, L$. When η_H, the

pro-industry incumbent selecting $(\hat{t}(\eta_L), 0)$ will obtain

$$v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_H, \rho)\hat{v}(\eta_H).$$

On the other hand, if he chooses $(\hat{t}(\eta_H), \hat{\tau}(\eta_H))$, he will obtain $\hat{v}(\eta_H)$. The definition of ρ^* (and also that of ρ_2^*) implies that

$$\begin{aligned} v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_H, \rho)\hat{v}(\eta_H) &> v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_H, \rho^*)\hat{v}(\eta_H) \\ &\geq \hat{v}(\eta_H). \end{aligned}$$

The first inequality comes from $\rho > \rho^*$ and the property that g is an increasing function of ρ. The second inequality comes from the definition of ρ^* (and also that of ρ_2^*). Therefore, the pro-industry incumbent chooses $(\hat{t}(\eta_L), 0)$ when η_H.

When η_L, the pro-industry incumbent selecting $(\hat{t}(\eta_L), 0)$ will obtain

$$v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_L, \rho)\hat{v}(\eta_L).$$

On the other hand, if he chooses $(\hat{t}(\eta_L), \hat{\tau}(\eta_L))$, he will obtain $\hat{v}(\eta_L)$. The definition of ρ^* (and also that of ρ_2^* and ρ_3^*) implies that

$$\begin{aligned} v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_L, \rho)\hat{v}(\eta_L) &> v_p(\hat{t}(\eta_L), 0) + \delta g(\eta_L, \rho^*)\hat{v}(\eta_L) \\ &\geq \hat{v}(\eta_L). \end{aligned}$$

Again, the first inequality comes from $\rho > \rho^*$ and the property that g is an increasing function of ρ. The second inequality comes from the definition of ρ^* (and also that of ρ_3^*). Therefore, the pro-industry incumbent prefers selecting $(\hat{t}(\eta_L), 0)$ rather than $(\hat{t}(\eta_L), \hat{\tau}(\eta_L))$ when η_L. Q.E.D.

Appendix B

This appendix gives the proof of proposition 5 in chapter 3. The net benefit function for industrialists is given by

$$NB^I = \frac{K(1-\theta_I)^2 (p^* - \eta)^2}{4(a + 2\theta_I - 1)}. \tag{A.1}$$

Differentiating (A.1) with respect to θ_I, θ_E, a, and η to obtain

$$\frac{dNB^I}{d\theta_I} = -\frac{K(a+\theta_I)(1-\theta_I)(p^*-\eta)^2}{2(a+2\theta_I-1)^2} < 0,$$

$$\frac{dNB^I}{d\theta_E} = 0,$$

$$\frac{dNB^I}{da} = -\frac{K(1-\theta_I)^2 (p^*-\eta)^2}{4(a+2\theta_I-1)^2} < 0,$$

$$\frac{dNB^I}{d\eta} = -\frac{K(1-\theta_I)^2 (p^*-\eta)}{2(a+2\theta_I-1)} < 0.$$

Note that $a + 2\theta_I - 1 > 0$ as $\hat{\tau}_I < \eta$. Also, note that $p^* - \eta = p^* - \hat{\tau} > 0$ to have a positive producer price. Then, the results follow. Q.E.D.

Appendix C

This appendix gives the proof of proposition 6 in chapter 3. The net benefit function for environmentalists is given by

$$NB^E = \frac{K\theta_E{}^2 (p^* - \eta)^2}{4(a + 2\theta_E)}. \tag{A.2}$$

Differentiating (A.2) with respect to θ_E, θ_I, a, and η to obtain

$$\frac{dNB^E}{d\theta_E} = \frac{K\left(a+\theta_E\right)\theta_E\left(p^*-\eta\right)^2}{2(a+2\theta_E)^2} > 0,$$

$$\frac{dNB^E}{d\theta_I} = 0,$$

$$\frac{dNB^E}{da} = -\frac{K{\theta_E}^2\left(p^*-\eta\right)^2}{4(a+2\theta_E)^2} < 0,$$

$$\frac{dNB^E}{d\eta} = -\frac{K{\theta_E}^2\left(p^*-\eta\right)}{2(a+2\theta_E)} < 0.$$

Note that $p^* - \eta = p^* - \hat{\tau} > 0$ to have a positive producer price. Then, the results follow. Q.E.D.

Appendix D

This appendix gives the proof of proposition 8 in chapter 3. The net benefit function for environmentalists in the presence of the industry lobby is given by

$$NB^{E'} = \frac{K(a+1)^2\theta_E^2\left(p^*-\eta\right)^2}{4(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)}. \tag{A.3}$$

First, differentiating (A.3) with respect to θ_E to obtain

$$\frac{dNB^{E'}}{d\theta_E} = \frac{K(a+1)^2\theta_E\left(p^*-\eta\right)^2\left(a+2\theta_I-1+\theta_E\right)}{2(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)}.$$

As $a+2\theta_I-1>0$, it follows that $a+2\theta_I-1+2\theta_E>0$ and $a+2\theta_I-1+\theta_E>0$. Thus, $dNB^{E'}/d\theta_E > 0$. Next, differentiating (A.3) with respect to θ_I to obtain

$$\frac{dNB^{E'}}{d\theta_I} = -\frac{K(a+1)^2\theta_E^2\left(p^*-\eta\right)^2}{(a+2\theta_I-1)^3(a+2\theta_I-1+2\theta_E)} - \frac{K(a+1)^2\theta_E^2\left(p^*-\eta\right)^2}{2(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)^2}.$$

Thus, $dNB^{E'}/d\theta_I < 0$ by the same reason as above. Differentiating (A.3) with respect to a to obtain

$$\frac{dNB^{E'}}{da} = -\frac{K(a+1)\theta_E^2\left(p^*-\eta\right)^2(1-\theta_I)}{(a+2\theta_I-1)^3(a+2\theta_I-1+2\theta_E)} - \frac{K(a+1)^2\theta_E^2\left(p^*-\eta\right)}{4(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)^2}.$$

Again, it follows that $dNB^{E'}/da < 0$. Finally, differentiating (A.3) with respect to η to obtain

$$\frac{dNB^{E'}}{d\eta} = -\frac{K(a+1)^2\theta_E^2\left(p^*-\eta\right)}{4(a+2\theta_I-1)^2(a+2\theta_I-1+2\theta_E)}.$$

As $p^*-\eta = p^*-\hat{\tau} > 0$, then $dNB^{E'}/d\eta < 0$. Q.E.D.

Appendix E

This appendix gives the proof of proposition 10 in chapter 3. The net benefit function for industrialists in the presence of the environmental lobby is given by

$$NB^{I'} = \frac{K[a(1-\theta_I)+\theta_E]^2\left(p^*-\eta\right)^2}{4(a+2\theta_E)^2(a+2\theta_I-1+2\theta_E)}. \tag{A.4}$$

First, differentiating (A.4) with respect to θ_I to obtain

$$\frac{dNB^{I'}}{d\theta_I} = -\frac{K[a(1-\theta_I)+\theta_E]\left(p^*-\eta\right)^2\left[a\left(a+2\theta_E+\theta_I\right)+\theta_E\right]}{2(a+2\theta_E)^2(a+2\theta_I-1+2\theta_E)^2} > 0.$$

Next, differentiating (A.4) with respect to θ_E to obtain

$$\frac{dNB^{I'}}{d\theta_E} = -\frac{K[a(1-\theta_I)+\theta_E]\left(p^*-\eta\right)^2}{2(a+2\theta_E)^3(a+2\theta_I-1+2\theta_E)^2}\cdot A,$$

where

$$A = [a(1-\theta_I)+\theta_E](a+2\theta_E) + a\left(1-2\theta_I\right)\left(a+2\theta_I-1+2\theta_E\right).$$

The sign of the first term in A is positive, while that of the second is ambiguous. However, if industrialists and environmentalists comprise a sufficiently small fraction in the total population, the sign of A becomes positive.[50] If this is the case, $dNB^{I'}/d\theta_E < 0$. Differentiating (A.4) with respect to a to obtain

$$\frac{dNB^{I'}}{da} = \frac{K[a(1-\theta_I)+\theta_E]\,(p^*-\eta)^2}{4(a+2\theta_E)^3(a+2\theta_I-1+2\theta_E)^2} \cdot B,$$

where

$$B = 2\theta_E(1-2\theta_I)(a+2\theta_I-1+2\theta_E) - [a(1-\theta_I)+\theta_E](a+2\theta_E).$$

Again, if industrialists and environmentalists comprise a sufficiently small fraction in the total population, the sign of B becomes positive, and hence $dNB^{I'}/da < 0$.[51] Finally, differentiating (A.4) with respect to η to obtain

$$\frac{dNB^{I'}}{d\eta} = -\frac{K[a(1-\theta_I)+\theta_E]^2\,(p^*-\eta)}{2(a+2\theta_E)^2(a+2\theta_I-1+2\theta_E)}.$$

As $p^*-\eta = p^*-\hat{\tau} > 0$, it follows that $dNB^{I'}/d\eta < 0$. Q.E.D.

[50] This can be confirmed by looking at the fact that for $\theta_I < 1/2$ the sign of the second term is always positive.

[51] For approximation, substituting $\theta_E = \theta_I = 0$ into B gives $B = -a^2 < 0$.