Trade, Transboundary Pollution, and Foreign Lobbying

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Abstract

In this paper, we explore the use of trade policy in addressing transboundary stock pollution problems such as acid rain and water pollution. We show that a tariff determined by the current level of accumulated pollution can induce the time path of emissions optimal for the downstream (polluted) country. But if the upstream (polluting) country can lobby the downstream government to impose lower tariffs, distortions brought by corruption and foreign lobbying lead to a rise in the upstream country's social welfare, and to a decrease in social welfare in the downstream country. Thus, the usefulness of trade policy as a tool for encouraging cooperation and internalizing transboundary externalities depends critically on the degree of governments' susceptibility to foreign political influence.

JEL classification: D72; F18; F59; Q56.

[1] The authors are grateful to Richard Arnott, Tom Crocker, Ariel Dinar, Linda Fernandez, George Frisvold, Robert Godby, Jason Shogren and two anonymous referees for their comments on earlier drafts. We also thank seminar participants at 6th Meeting on Game Theory and Practice in Zaragoza, Spain, Heartland Environmental and Resource Economics Workshop in Ames, IA, Western Economic Association International 82nd Annual Conference in Seattle, WA, 10th Occasional Workshop on Environmental and Natural Resource Economics in Santa Barbara, CA, for their helpful comments. All remaining errors are our own.

1. Introduction

Transboundary pollution poses a special challenge to regulators because of the features that distinguish it from national environmental problems. Transboundary pollution is characterized by damages occurring in one country owing to the actions of one or more other countries. As long as there exists no supranational institution with complete authority to enforce cooperation, and no national government can regulate polluters located outside of its political jurisdiction, Pigouvian taxes to control transboundary pollution are not feasible. However, as long as each country can influence the payoffs of another, there is a need to analyze the strategic interactions between the affected countries. Such interactions may not necessarily lead to cooperative outcomes either. While there have been attempts to negotiate international cooperation to regulate some forms of transboundary pollution, attaining such a cooperative solution at the international level has been difficult, especially when countries have asymmetric incentives.[2]

While transboundary pollution has proven difficult to regulate, it is becoming a growing regional and global environmental problem (UNEP 2002; OECD 2007). Although the most well-known example of transboundary pollution is greenhouse gas emissions and global warming, some significant transboundary environmental problems are not reciprocal but unidirectional; i.e., they involve pollution originating in one country causing damages mainly in another country or region. Acid rain, for example, has become one of the major environmental concerns in North America, Europe, and Asia, causing damages that amount to billions of dollars

[2] For example, several upwind countries, including the United Kingdom, refused to ratify the 1985 Helsinki protocol on the Reduction of Sulfur Emissions on their Transboundary Fluxes as it was estimated that the costs of abatement for these countries would exceed the domestic environmental benefits (Hakan Nordstrom and Scott Vaughan 1999).

(David Newbery 1990, Yoko Nagase and Emilson Silva 2000, 2007). Due to prevailing winds, acid rain precursors often accumulate well beyond the borders of the polluting country.[3] There are also examples of transboundary pollution involving water pollution. The contamination of seas and rivers is frequently attributed to pollutants crossing national boundaries and accumulating in neighboring regions and countries. For instance, the eutrophication[4] of the North and Black Seas, which results from agricultural run-off brought from upstream countries via rivers, is responsible for radical changes in marine ecosystems and is affecting fishing and tourism in countries where coastal waters are relatively shallow such as Denmark, Romania, and Ukraine.[5]

If cooperation between the countries to regulate transboundary pollution is not forthcoming, the government of the affected country has limited options to control the externality imposed on it by the polluting country. Indeed, it has been argued that trade policies are one of the few available instruments for creating or increasing the incentives to internalize such a cross-border externality. The role of trade policy in addressing unidirectional transboundary pollution is twofold. First, a number of studies show that trade policy may serve as a "second-best"

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[3] It is well documented that as a result of their unfortunate downwind location, much of the US production of SO_2 and NO_x is deposited in Canada and much of the UK production is deposited in Scandinavian countries (e.g., Newbery 1990). It has also been shown that Chinese emissions of SO_2 cause acid rain in Japan (Nagase and Silva 2007).

[4] Eutrophication is an over-enrichment of the water bodies with phytoplankton due to overloading with nitrogen and phosphorus nutrients.

[5] See Basak Bayramoglu (2006). Among other cases that have historically been important are heavy metals and chloride pollution suffered by downstream countries on the Danube and Rhine Rivers (Thomas Bernauer and Peter Moser 1996, Jacqueline McGlade 2000), and salinity problems in the lower basin of the Colorado River where it crosses the Mexican-American border (Karl-Goran Maler 1990).

instrument to control the externality, playing a role that is somewhat similar to the role a Pigouvian tax performs within a single political jurisdiction (William Baumol and Wallace Oates 1988, James Markusen 1975, Brian Copeland 1996). Second, it has been suggested that trade policy may serve as a mechanism for promoting cooperation between countries linked by the externality. For instance, Nordstrom and Vaughan (1999, p. 3), note that "while trade measures are rarely, if ever, the first-best policy for addressing environmental problems, governments have found trade measures a useful mechanism for encouraging participation in and enforcement of multilateral environmental agreements in some instances, and for attempting to modify the behavior of foreign governments in others."

While it has been argued that such a use of trade measures may create or increase the incentive to cooperate for the polluting country, little attention has been given to the fact that it may also create other incentives that could adversely effect the externality regulation and lead to the aggravation of the unidirectional transboundary pollution problem. Failure to identify and consider these negative incentives may lead to misleading conclusions regarding the effectiveness of trade policy in promoting cooperation between the countries linked by the externality. Recent events have brought to public attention the significant extent of foreign lobbies' involvement in domestic economic policymaking.[6] International trade is by far the most common issue targeted by foreign lobbies. Being a key player in the world markets, the United

[6] These include the connection between foreign lobbying and 2008 U.S. presidential campaign fundraising (Will Evans and Avni Patel 2008, Jim McElhatton and Jerry Seper 2008), allegations of foreign contributions during fundraising for the 1996 U.S. presidential campaign (Bob Woodward and Brian Duffy 1997, Allan Millar 1996); the controversy surrounding the Chinese government recently hiring the top lobbying firms to represent Chinese interests in the U. S. (Marina Guevara 2005) or the recent investigation by Harper's Magazine's Ken Silverstein (2007) revealing the inside details about foreign lobby industry in Washington DC.

States economy, in particular, has become a focus of lobbying by foreign governments and private organizations, trying to achieve more favorable trade regime (Andreas Jobst 2002, Hiau Kee et al. 2007). Another trend observed is that increasingly foreign lobbying is affecting domestic environmental policies and regulations.[7] Such lobbying influence may be particularly effective in situations where two countries are linked by trade flows and unidirectional transboundary pollution. Since trade and environmental policies affect income distribution within and between the countries, they may create incentives for *both* domestic and foreign special interest groups to influence domestic policy decisions. While a few recent studies have considered how the presence of *domestic* environmental lobbies may affect the determination of trade and environmental regulations when trading countries share a cross-border pollution externality (Paola Conconi 2003, Nuno Limao 2005), to our knowledge none have investigate the role of *foreign* lobbying in determining environmental and trade policy outcomes.

By examining how the foreign lobbying activity may affect environmental and trade outcomes in two countries linked by a unidirectional transboundary pollution externality, this paper bridges two distinct literatures on the political economy of trade issues. Most of the analytical contributions in this area build on the common agency model of Gene Grossman and Elhanan Helpman (1994) where policy is determined by interactions between the policymaker and lobby groups offering the government political contributions contingent on policy decisions made. Although the focus of the Grossman-Helpman model is on trade policy and no environmental externalities are considered, a number of extensions do introduce such

[7] For example, the LobbyWatch project of the Center for Public Integrity (http://www.publicintegrity.org/lobby/) reports that British Petroleum plc, one of the biggest foreign spenders on Washington DC lobbying, lobbied almost as much on environmental issues and Superfund as it did on matters related to oil and gas.

externalities (e.g., Edward Barbier et al. 2005, Richard Damania and Per Fredriksson 2003, Richard Damania and John List 2000). The second set of studies extends the Grossman-Helpman model to consider the competing influence of domestic and foreign lobbies in the political process of trade policy formation (Kishore Gavande et al. 2006), which is supported by empirical evidence on the role of foreign lobbies in influencing the U.S. trade policies such as export growth promotion and tariff preferences (Jobst 2002, Kee et al. 2007).

An important shortcoming in the extant literature is that existing studies generally use a static framework. This framework is limited in two key respects. First, it tends to regard pollution as a flow, despite the fact that the majority of pressing transboundary pollution problems (such as the acid rain and water pollution examples mentioned above) are characterized by damages caused by pollution stock. This suggests a need for a dynamic analysis of strategic decision-making. In this paper we develop such a model to consider trade policy as a regulation tool when externality arises from a transboundary *stock* pollutant.[8] Second, lobbying could also be thought of a process of "investing" in political capital. Lobbying "influence" often has to be built and maintained over time. Thus effective lobbying requires close monitoring of legislative processes and maintaining contact with politicians in and out of administration. In other words, "many economists commonly refer to foreign lobbying as a form of 'investing' in trade" (Jobst 2002, p. 9) but then ignore the 'investment' implication of such lobbying efforts. We address this issue by treating foreign lobbying as an investment in the political capital stock that allows one

[8] Such modeling approach is in line with contributions to environmental economics literature that study transboundary pollution problems using differential games (e.g., Engelbert Dockner and Ngo Van Long 1993, John List and Charles Mason 2001, Linda Fernandez 2002).

country to influence the policy choice made by the other country's government.[9] This approach requires us to use a differential game to characterize the dynamic interaction of the two governments and to examine the optimal strategies that emerge in this setting.

We construct a partial equilibrium model to consider two countries, Upstream and Downstream, characterized by two interactions: unidirectional trade and unidirectional transboundary pollution externality. The Upstream country produces and exports to Downstream a consumption good that generates pollution during the manufacturing process. To highlight the case when two countries have conflicting interests and upstream country has no incentives to control for pollution, we assume that Upstream does not suffer any damages from pollution. Upstream emissions contribute to a stock of pollution that only causes damages in Downstream. As it has no authority to directly control Upstream emissions, the Downstream government cannot use environmental policy to regulate the externality. It can, however, choose a sequence of tariffs as a "second-best" measure to address the problem.[10] Using this dynamic model, we show that while a tariff is levied on the flow of imports at each instant, the tariff is determined by accumulated pollution. Thus, the time path of optimal tariffs is tied to the evolution of the

[9] Hossein Farzin and Jinhua Zhao (2003) use a similar approach. They develop a dynamic model to examine the optimal decisions of a typical firm that foresees a possible future increase in domestic pollution tax and can respond by investing in lobby capital and abatement capital.

[10] Like earlier studies of tariffs as "second-best" tools to tackle transboundary pollution, we make a limiting assumption that Downstream imports the good whose production causes damages in Downstream and thus a tariff against imports is able to reduce the output of the polluting industry. While the WTO rules generally do not allow its members to increase import tariffs, the GATT Article XX (paragraphs b and g) gives limited freedom to use trade measures to protect human health, biodiversity, or to conserve exhaustible natural resources. In cases of transboundary air and water pollution it is conceivable that trade instruments might be used to induce the government with jurisdiction over polluter to address the externality (UNEP 2005; Bradly Condon 2004).

pollution stock. This linkage provides a motive for the Upstream government to attempt to influence Downstream's decision by using political economic tools such as lobbying. Our analysis suggests that the success of trade policy as a tool of promoting cooperation in solving transboundary pollution problems depends crucially on the degree of Downstream government's susceptibility to foreign political influence.[11]

2. A Model of Transboundary Pollution Control

One of the main criticisms of using a trade tariff to tackle a transboundary externality is that instead of addressing the source of the externality, i.e., pollution, any tariff targets the exchange of goods. Static "second best" models (*e.g.*, Markusen, 1975) usually assume that emissions are directly proportional to foreign output and do not evolve over time, and thus find that import tariffs are optimal. Here we demonstrate that if the externality arises from a stock pollutant, the optimal import tariff at every instant is endogenously determined by the current level of the pollution stock. In subsequent sections, we extend this basic trade and transboundary pollution model to include the influence of foreign lobbying.

Consider two countries, "Upstream" and "Downstream." A single consumption good is produced only in Upstream with a given fixed endowment of factors of production and a given technology. At the trading price, there is an excess supply of this good in the Upstream country, which is being exported to the Downstream country. Consumers are homogeneous within each country, but may be heterogeneous across countries. At every instant, Upstream production $Q(t)$ in results in a flow of emissions, $E(t)$, which we assume is given by a fixed proportions relation. Accordingly, $E(t) = \varphi Q(t)$.

[11] Here we restrict our attention to the comparison of two second-best scenarios and do not consider the socially optimal solution to the problem. The comparison of our results to the optimum would involve a contrast between the effects of the environmental tax (first-best) and a tariff (not two different tariffs), which would lead to obvious results.

The amount of pollutants emitted by the Upstream country contributes to the stock of pollution, Z, which evolves according to the following equation of motion: [12]

$$\dot{Z} = E - kZ, \tag{1}$$

where k represents the rate of pollution decay. The initial stock of the pollutant is Z_0. Although pollution is generated by emissions in the Upstream country, we assume that the environmental damage from the stock of pollution is realized in Downstream only and that there are no damages from the flow of emissions. Downstream damages, $D(Z)$, are an increasing and convex function of the pollution stock. For expositional clarity, we assume marginal damages are linear in the pollution stock, with

$$D(Z) = \frac{s}{2} Z^2,$$

where $s > 0$ is the rate of increase of the marginal pollution damage. Such externalities emerge when the pollutant is transmitted via air, rivers, lakes, or precipitation, and include important cases such as the deterioration of soil and water quality attributed to acid deposition and the degradation of water quality due to accumulated emissions of heavy metals or agricultural runoff.

When such pollution externalities are exported unidirectionally from one country to another, no authority has the ability to intervene and enforce cooperation. Thus countries will act only if their efforts ultimately serve their own interest. Since the Upstream country does not suffer any damages from the pollution stock, we assume that it does not impose any environmental regulations on its firms. The Downstream government, in turn, does not have political authority to address the source of pollution directly by imposing a Pigouvian tax or

[12] From now on, unless otherwise stated, we will suppress the time argument t.

abatement standard on foreign producers. However, it can indirectly tackle the externality by imposing a tariff, τ, on imports from the Upstream country. The tariff lowers the price in Upstream and forces firms to cut down the level of production and with it the flow of transboundary emissions, contributing to the pollution stock.[13]

For any given level of tariff, equilibrium conditions for both countries' markets imply the level of production by Upstream producers, the level of exports to Downstream, and the equilibrium after-tariff prices in both countries are all determined by Downstream's choice of the tariff: $Q(\tau)$, $Y(\tau)$, $p(\tau)$. This allows us to write the net benefit functions for Upstream and Downstream, respectively, in the following form:

$$CS_u\big(Q(\tau) - Y(\tau)\big) + (p(\tau) - \tau)Q(\tau) - C_u\big(Q(\tau)\big) \equiv W_u(\tau), \tag{2}$$

$$CS_d\big(Y(\tau)\big) + \tau Y(\tau) - D(Z) \equiv W_d(\tau) - \frac{s}{2}Z^2, \tag{3}$$

where CS_i represents consumer surplus in country $i = u, d$, τY(a) is the tariff revenue collected by Downstream and C_u is the cost of production in Upstream. Since Q is influenced by the choice of tariff, so are the associated emissions, and thus we may write $E(\tau)$. As emissions are proportional to output, which in turn is declining in the tariff τ, the flow of emissions is decreasing with tariff: $E(\ ) < 0$. Through this impact on emissions, τ influences the evolution of the stock of pollution.

To allow analytically tractable results, we will focus on the case with linear supply Upstream and linear demand in both Upstream and Downstream. These structural assumptions gives rise to a linear-quadratic model, which facilitates the analysis.[14] In particular, the payoff functions W_d and W_u are both quadratic in τ:

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[13]We assume that Downstream has the market power to influence the terms of trade through its tariff.

[14] While a more general framework can be employed in the simple version of the model analyzed in this section, it is generally difficult to make headway in differential games without imposing stark structural assumptions, such as

$$W_d(\tau) = W_d^0 + AY_0\tau - \frac{b(1+A)(1-A)}{2}\tau^2,$$

$$W_u(\tau) = W_u^0 - AY_0\tau + \frac{bA(1-A)}{2}\tau^2,$$

where A and b are positive parameters, Y_0 is the pre-tariff level of exports from Upstream to Downstream and W_d^0 and W_u^0 are the payoffs received by the Downstream country and Upstream country, respectively, in the absence of a tariff.[15] Both countries' payoff functions are decreasing in tariff in the relevant range.[16] In addition, $Q(\tau)$ is linear and decreasing in τ, which implies that emissions are as well:

$$E(\tau) = E^0 - \lambda\tau,$$

where E^0 is the level of emissions generated by the equilibrium level of output produced before the tariff imposition.[17]

The Downstream government takes the Upstream government's strategy as given[18] and chooses a sequence of tariffs that maximizes the discounted stream of net benefits Erreur ! Source du renvoi introuvable., taking into account the evolution of the pollution stock. We assume the Downstream government uses a Markov strategy, *i.e.* one that is based on a payoff-relevant state variable – here, the pollution stock (Karp, 1992; Mason and Polasky,

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the linear-quadratic framework. To keep the discussion of this section on a parallel footing to that of the later sections, we opt to restrict attention to the linear-quadratic framework here.

[15] Write Downstream demand as $Q_d^d = a - bP$ and write Upstream demand and supply as $Q_u^d = a_u - b_uP, Q_d^s = dP$. Then A = b/(b+d+$b_u$); notice that $A \in (0,1)$. A referee points out that at a sufficiently large tariff imports are completely eliminated. Denote the smallest such tariff as τ^p; increases in the tariff above τ^p would have no effect on Upstream. It can be shown that $\tau^p = \frac{Y_0}{b(1-A)}$ and so by restricting our attention to values $\tau \leq \frac{Y_0}{b(1-A)}$ we ensure the tariff does have an effect on emissions.

[16] Since we assumed that Downstream is a large country, there is a tariff that maximizes Downstream's static welfare, namely $\tau^0 = \frac{AY_0}{b(1-A^2)}$. The tariff policy we are investigating in this paper implies a level above τ^0; accordingly, we restrict our attention to values $\tau \geq \frac{AY_0}{b(1-A^2)}$.

[17] The constant rate of decrease in emissions, λ, is equal to d(1-A)ξ, where d is the slope of the upstream supply curve, ξ is the constant proportion of emissions to output, and A is the parameter introduced above.

[18] In this section, Upstream behaves as a static maximizer, so its 'strategy' is trivial. In the next section Upstream chooses a more sophisticated strategy.

1997, 2002; Mason, 1997).[19] This strategy dictates the optimal tariff level for every possible level of Z along the transition path to the steady state.

The objective of the Downstream government is to:

$$\max_{\tau} \int_0^{\infty} e^{-rt}[W_d(\tau) - D(Z)]dt$$

$$\text{subject to } \dot{Z} = E(\tau) - kZ; Z(0) = Z_0;\ Z \geq 0; \tau^p \geq \tau \geq \tau^0;$$

where r is the discount rate, common to both countries, and the constraining values on Downstream'schoice of tariff are $\tau^0 = \frac{AY_0}{b(1-A^2)}$ and $\tau^p = \frac{Y_0}{b(1-A^2)}$ (as discussed in footnotes 15 and 16). The current-value Hamiltonian for this optimization problem can be written as

$$H = W_d(\tau) - D(Z) + \theta[E(\tau) - kZ]$$

$$= W_d^0 + AY_0\tau - \frac{b(1+A)(1-A)}{2}\tau^2 - \frac{s}{2}Z^2 + \theta[E_0 - \lambda\tau - kZ],$$

$$= W_d^0 + AY_0\tau(1 - \frac{1}{2}\frac{\tau}{\tau^0}) - \frac{s}{2}Z^2 + \theta[E_0 - \lambda\tau - kZ],$$

where θ is the co-state variable representing the shadow value of pollution for the Downstream government, which presumably is negative.

The necessary conditions for the maximum principle require that the optimal tariff sets the marginal welfare cost associated with the tariff equal to the marginal benefit represented by the shadow value of the marginal pollution reduction,[20]

[19] Aside from the motive of following the extant literature, we also want the analysis in this section to be directly comparable to that of the following sections. As we assume governments use Markov-Perfect strategies below, it is appropriate to assume the Downstream government uses a Markov strategy here.

[20] The optimal tariff must also satisfy the two inequality constraints $\frac{Y_0}{b(1-A)} \geq \tau \geq \frac{AY_0}{b(1-A^2)}$. The second of these will automatically be satisfied so long as the shadow value on pollution is negative, which is a mild restriction; for the first constraint to hold the shadow value can not be too large in magnitude: $\theta \geq -\frac{Y_0}{\lambda}$. (In the event this restriction does not hold, Downstream would set the tariff at the prohibitive level, and there would be no trade.) In light of Proposition 1 below, this restriction can be cast in terms of the various parameters; we assume this holds true in the remainder of the paper.

$$W_d'(\tau) = -\theta E'(\tau) \leftrightarrow \tau = \tau^0 - \frac{\lambda}{b(1-A^2)}\theta \tag{4}$$

and that the shadow price of pollution evolves at the rate equal to the marginal damage from pollution less the opportunity cost of cutting down emissions by one unit,

$$\dot{\theta} = \mathrm{sZ} + (\mathrm{r}+\mathrm{k})\theta. \tag{5}$$

By time-differentiating equation (4) and substituting from equations (4) and (5), we obtain the equation of motion for the optimal tariff as

$$\dot{\tau} = -\frac{\lambda s}{b(1-A^2)}Z - (r+k)\frac{\lambda}{b(1-A^2)}\theta = -\frac{\lambda s}{b(1-A^2)}Z + (r+k)(\tau-\tau^0). \tag{6}$$

The equation of motion for the state variable is found by substituting the expression for $E(\tau)$ into equation (1), which gives

$$\dot{Z} = E^0 - \lambda\tau - kZ. \tag{7}$$

The solution to this optimization problem can be viewed as a system of first-order linear differential equations, obtained by combining equations (6) and (7)

$$\begin{pmatrix}\dot{\tau}\\ \dot{Z}\end{pmatrix} - \begin{pmatrix} r+k & -\frac{\lambda s}{b(1-A^2)} \\ -\lambda & -k \end{pmatrix}\begin{pmatrix}\tau\\ Z\end{pmatrix} = \begin{pmatrix}-(r+k)\tau^0\\ E^0\end{pmatrix}. \tag{8}$$

The solution to this system consists of a general solution to the homogeneous differential equation, which is obtained by removing the constants from the right-hand side of the system, together with a specific solution. The general solution is a pair of exponentials, $(\tau, Z) = (\kappa_\tau e^{\rho t}, \kappa_Z e^{\rho t})$. Substituting into the system (8) leads to the characteristic equation

$$(\rho - r - k)(\rho + k) - \frac{\lambda^2 s}{b(1-A^2)} = 0, \tag{9}$$

which the parameter ρ must satisfy. It is easy to see that one of the two roots in the characteristic equation, call it ρ_1, is negative and smaller than –k, while the other root, call it ρ_2, is positive and larger than r+k. The general solution to the homogeneous equation then takes the form $(\tau, Z) =$

$(\kappa_{\tau 1} e^{\rho_1 t} + \kappa_{\tau 2} e^{\rho_2 t}, \kappa_{Z1} e^{\rho_1 t} + \kappa_{Z2} e^{\rho_2 t})$. The complete solution must also satisfy a transversality condition, which requires that either the shadow value converges to zero or the state variable converges to a steady state; in either event the contribution from the exponential component must tend to zero. But this requires the coefficients $\kappa_{\tau 2} = \kappa_{Z2} = 0$. It then follows that the complete solution is $(\tau, Z) = (\kappa_{\tau 1} e^{\rho_1 t} + \tau^e, \kappa_{Z1} e^{\rho_1 t} + Z^e)$, where ($\tau^e$, Z^e) is the steady state for the system. The solution must also satisfy the initial condition Z(0) = Z_0, which implies $\kappa_{Z1} = Z_0 - Z^e$; we may then write $\kappa_{\tau 1} = h\kappa_{Z1}$ for some factor of proportionality *h*. The associated steady state (Z^e, τ^e) is characterized by the conditions:

$$\tau^e = \tau^0 + \frac{\lambda s}{(r+k)b(1-A^2)} Z^e; \tag{10}$$

$$Z^e = \frac{E(\tau^e)}{k} = \frac{E^0}{k} - \frac{\lambda}{k}\tau^e. \tag{11}$$

For later reference, we note that the steady state value of the shadow price of pollution is

$$\theta^e = -\frac{sZ^e}{r+k} = -\frac{D'(Z^e)}{r+k}, \tag{12}$$

the negative of the capitalized value of marginal damages at the steady state stock. Figure 1 presents a phase diagram for the problem.

[Figure 1 here]

The first result summarizes the steady state associated with this problem.

PROPOSITION 1: *There is a unique globally and asymptotically stable solution to the Downstream government's optimization problem that results in a steady state tariff τ^e and a steady state pollution stock Z^e given by*

$$\tau^e = \tau^0 + \frac{\lambda s(E^0 - \lambda\tau^0)}{k(r+k)b(1-A^2) + \lambda^2 s};$$

$$Z^e = \frac{(r+k)b(1-A^2)[E^0 - \lambda A Y_0]}{k(r+k)b(1-A^2) + \lambda^2 s}.$$

If the initial stock of pollution is smaller than the steady state level both the tariff and pollution stock rise monotonically from the initial level to the steady state level. The optimal tariff can be described by the feedback rule

$$\tau(Z) = hZ + \tau^e - hZ^e.$$

Proof. The solution was derived above; the steady state values may be derived by solving the system of equations (10) – (11). That both tariff and pollution stock are monotonic follows from the functional forms; that both rise if the initial pollution is small requires that $h > 0$. Inserting the specific functions into the homogeneous differential equation for Z, combining terms and evaluation at $t = 0$ yields $h = \frac{\kappa_{\tau 1}}{\kappa_{Z1}} = -\frac{(\rho_1 + k)}{\lambda}$. As noted above, $\rho_1 < -k$, which guarantees $h > 0$. The feedback rule is then readily obtained by substitution. Q.E.D.

In earlier static "second-best" models the players' environment is taken as exogenous, rather than evolving endogenously as a result of their actions: pollution is often assumed to be directly proportional to foreign output, making an import tariff optimal. By contrast, equation (13) shows how the optimal tariff at every instant is endogenously determined by the current level of the pollution stock. The coefficient of proportionality h captures the marginal response of the Downstream government to an increase in the pollution stock. Since h is positive, the Downstream authority reacts to an increase in the stock of pollution by raising the tariff. While the tariff still targets the flow of goods, at every point in time it is adjusted to reflect the current level of the pollution stock, the source of the externality. We show in Appendix A that h is increasing in s and λ, and decreasing in k and r. If the rate of change of the marginal damages from pollution, s, rises or if total emissions decrease faster with the tariff, at every instant, the Downstream government will respond to an increase in pollution by a larger increase in tariff. By contrast, increases in the rate of discount, r, or the rate of pollution decay, k, lead to a decrease in the marginal tariff response to a higher pollution level by the Downstream policymaker, since both r and k are increasing the opportunity cost of reducing emissions via tariff imposition.

The equilibrium emission path in this simple model can also be contrasted to those found in earlier papers on transboundary pollution problems (Dockner and Long 1993, List and Mason 2001). These studies assume the existence of an over-arching regulatory authority that can control emissions. This authority chooses the rate of emissions for both of the countries, with the goal of maximizing the joint welfare of the two regions. In our model, the time path of the pollution control is determined by unilateral and non-cooperative actions of a single policymaker, the government of the Downstream country. Welfare maximization problem of this government, however, contains the information about the effect of the policy on the other country's welfare, implicit in the volume of trade and price changes over time, induced by the tariff.

3. Transboundary Pollution Control in the Presence of Foreign Lobbying

The downstream tariff choice determines the level of welfare in the Upstream country, with increased tariffs lowering Upstream's net surplus. If this tariff rises monotonically over time, as will be the case if the initial pollution stock is smaller than the steady state level, Upstream's welfare falls monotonically. The implication is that Upstream has an incentive to take actions in an attempt to blunt the growth of the tariff. But to do so credibly, the actions taken by Downstream must be linked to some observable, payoff-relevant variable.

In this section, we develop an extension to the model, which assumes that the Upstream country can "invest" in political capital through lobbying to influence the actions of the Downstream government. There is a natural interpretation to this approach: the Upstream government constructs a conduit for channeling funds into a lobbying agency, which the

Upstream government uses to exert pressure upon the Downstream government to adjust the tariff path. We interpret the establishment of this lobbying agency and its activities as an investment in political capital. To fix ideas, one can think of this stock of political capital as a fund of actual financial capital, which is used to establish and expand the lobbying agency initially, and to make contributions to political parties, candidates or election campaigns. The accumulated influence over the legislative members in Downstream may be translated into majority of votes necessary to make a tariff policy decision. Increases in political capital allow the Upstream government to exert a greater influence on the Downstream policymaker's tariff choice, leading to increased Upstream welfare.[21]

The political capital, P, is assumed to evolve over time according to the following rule:

$$\dot{P} = I - \delta P, \tag{13}$$

where I is the level of investment in political capital by the Upstream government, and δ is the rate of depreciation of political capital. Depreciation captures the notion that past lobby contributions are not as effective as current ones in influencing current policy determination. Investment in political capital entails an opportunity cost $\varphi(I)$ to Upstream, which we assume is given by the quadratic function $\varphi(I) = I^2/2$.

When the Upstream country engages in lobbying for a less stringent tariff policy, it is no longer acting as a static player in the game. With both countries now making dynamic decisions that affect each player's payoffs, the appropriate model for our analysis is a differential game. We assume that both governments use Markov-perfect (feedback) strategies. These strategies are

[21] That players might believe such lobbying could influence behavior seems highly likely: in the US, billions of dollars are devoted to lobbying activities annually. Moreover, a recent US Supreme Court decision (Citizens United v. Federal Election Commission, 558 U.S. 08-205 (2010), 558 U.S. ——, 130 S.Ct. 876, January 21, 2010) explicitly protects organizations' right to pursue a political agenda; the majority opinion specifically avoids determining whether there is a "compelling governmental interest in limiting foreign influence over the Nation's political process." Apparently it is fair game for foreign interest to engage in political lobbying, at least in the US.

decision rules that dictate optimal actions of the respective players conditional on the current values of the pollution stock $Z(t)$ and political capital stock $P(t)$, which summarize the latest available information of the dynamic system. Thus Markov perfect strategies determine a subgame-perfect equilibrium: at every time t and for every possible value of $Z(t)$ and $P(t)$, the strategy defines an equilibrium set of decisions independent of previous actions.

Assuming that the Downstream government plays the Markov strategy $(Z(t), P(t))$, the Upstream government chooses the time path of investment by solving the following maximization problem:

$$\max_I \int_0^\infty e^{-rt}[W_u(\tau(Z,P)) - \tfrac{1}{2}I^2]dt$$

$$\text{subject to } \dot{Z} = E\big(\tau(Z,P)\big) - kZ; Z(0) = Z_0;\ \tau^p \geq \tau \geq \tau^0;$$

$$\dot{P} = I - \delta P; P(0) = 0; P \geq 0;\ I \geq 0.$$

We solve this problem using Pontryagin's maximum principle. The current-value Hamiltonian is formulated as

$$H_u = W_u\big(\tau(Z,P)\big) - \tfrac{1}{2}I^2 + \xi_Z\big[E\big(\tau(Z,P)\big) - kZ\big] + \xi_P[I - \delta P],$$

where ξ_Z represents the shadow price of pollution and ξ_P represents the shadow price of political capital for the Upstream country. The maximum condition and the adjoint equations for the shadow prices of pollution and political capital, respectively, are

$$I = \xi_P; \tag{14}$$

$$\dot{\xi}_Z = (r+k)\xi_Z - [W_u'(\tau) + \xi_Z E'(\tau)]\frac{\partial\tau(Z,P)}{\partial Z}$$

$$= (r+k)\xi_Z + [Y_o - b(1-A)\tau + \lambda\xi_Z]\frac{\partial\tau(Z,P)}{\partial Z}; \tag{15}$$

$$\dot{\xi}_P = (r+\delta)\xi_P - [W_u'(\tau) + \xi_P E'(\tau)]\frac{\partial\tau(Z,P)}{\partial P}$$

$$= (r + \delta)\xi_P + [Y_o - b(1 - A)\tau + \lambda\xi_P]\frac{\partial\tau(Z,P)}{\partial P}. \quad (16)$$

The partial derivatives $\partial\tau(Z,P)/\partial Z$ and $\partial\tau(Z,P)/\partial P$ capture the responses of the Downstream government to an increase in the two stocks. One expects that the Downstream government will increase the tariff when the pollution stock increases, i.e., $\partial\tau(Z,P)/\partial Z > 0$, and that increases in the political capital stock will induce the Downstream government to reduce the tariff, i.e., $\partial\tau(Z,P)/\partial P < 0$. The maximum condition (14) implies that, at every instant, the Upstream government chooses the level of investment in political capital that equates the marginal cost of such investment and the shadow price of the political capital. Equation (15) shows that the rate of change in the shadow price of pollution for the Upstream government is determined by the opportunity cost of reducing emissions by one unit, marginal reduction in Upstream's net surplus induced by that unit of emissions, and marginal contribution of that emission unit to the current value of the pollution stock. The evolution rule for the shadow price of political capital, (16), implies that the shadow price of $P(t)$ changes at the rate determined by the opportunity cost of holding on to a unit of political capital, marginal change in the current level of welfare in Upstream induced by that unit, marginal contribution of that unit to the current value of pollution stock. The system of equations (14)-(16) illustrates that while the Upstream country is not being adversely affected by the stock of pollution, strategic considerations make the Upstream policymaker account for pollution accumulation in determining her strategy.

Politics adds yet another layer to the Downstream policymaker's decision process: the choice of the optimal tariff strategy is now influenced by lobbying efforts of the Upstream government and, in particular, by the level of political capital at every instant. In the spirit of Grossman and Helpman (1994), we assume that the Downstream government's objective function in this case is represented by the discounted sum of citizens' welfare and by the additional utility that the Downstream policymaker derives from political contributions made by the Upstream government. Citizen welfare is made up of three terms: the utility from consuming the imported product, which is a function of the tariff level, $W_d(\tau)$; the pollution damages, $D(Z) = \frac{s}{2}Z^2$; and the benefits from the flow of information that lobbying provides, $b(I)$.[22] We assume the benefits from information are also quadratic, $b(I) = \beta I^2/2$, so as to retain the linear-quadratic structure. The Downstream decision-maker's "additional utility" represents the benefits he derives from political capital, which could reflect explicit financial impacts, as in the case of overt graft, or implicit benefits, as in the case where the decision-maker derives utility from being in power and believes the political capital stock will aid in the endeavor. We model this political influence of the Upstream government, achieved by the accumulation of political capital, as an increasing function of the political stock: $F(P) = fP - \frac{1}{2}P^2$.

Assuming that the Upstream government plays the Markov-perfect strategy $I(Z,P)$, the Downstream government chooses the time path of the tariff by solving the following maximization problem:

$$\max_{\tau} \int_0^{\infty} e^{-rt}[W_d(\tau) - \frac{s}{2}Z^2 + \frac{\beta}{2}I(Z,P)^2 + fP - \tfrac{1}{2}P^2]dt$$

$$\text{subject to } \dot{Z} = E(\tau) - kZ, Z(0) = Z_0, \tau^p \geq \tau \geq \tau^0,$$

$$\dot{P} = I(Z,P) - \delta P, P(0) = P_0, I(Z,P) \geq 0.$$

The current-value Hamiltonian for this problem can be written as:

$$H_d = W_d(\tau) - \tfrac{s}{2}Z^2 + \tfrac{\beta}{2}I(Z,P)^2 + fP - \tfrac{1}{2}P^2 + \eta_Z[E(\tau) - kZ] + \eta_P[I(Z,P) - \delta P],$$

[22] The Supreme Court decision we discussed in the preceding footnote implicitly views lobbying actions as beneficial to the typical citizen.

where η_Z is the shadow value of pollution and η_P is the shadow value of political capital for the Downstream government; as above, η_Z is presumably negative. Because the Downstream government is susceptible to lobbying, one also presumes that η_P is positive. The maximum principle conditions are

$$W_d'(\tau) = -\eta_Z E'(\tau) \leftrightarrow \tau = \frac{AY_0}{b(1-A^2)} - \frac{\lambda}{b(1-A^2)}\eta_Z; \tag{17}$$

$$\dot{\eta}_Z = (r+k)\eta_Z + sZ - [\beta I(Z,P) + \eta_P]\frac{\partial I(Z,P)}{\partial Z}; \tag{18}$$

$$\dot{\eta}_P = (r+\delta)\eta_P - f + P - [\beta I(Z,P) + \eta_P]\frac{\partial I(Z,P)}{\partial P}. \tag{19}$$

The partial derivative $\partial I(Z,P)/\partial Z$ measures the marginal response of the Upstream authority to an increase in the stock of pollution, which one expects to be positive: increases in the pollution stock increase the Upstream decision-maker's incentive to invest in political capital and lobby for the lower tariff rate. The partial derivative $\partial I(Z,P)/\partial P$ measures the marginal rate of investment induced by an increase in the political capital stock, which one expects to be negative as a result of diminishing returns. Equation (17) implies that the optimal tariff chosen by the Downstream government sets the marginal loss of net payoffs, resulting from the tariff imposition, equal to the shadow value of the marginal decrease in combined emissions induced by this tariff. Comparing with equation (4), we see that lobbying will matter only insofar as it changes the shadow value of pollution for the Downstream decision-maker, *i.e.* if $\eta_Z \neq \theta$.

Equation (18) shows that the shadow value of pollution evolves at a rate determined by the opportunity cost of reducing emissions by one unit, the marginal damages caused by that unit, and also by the marginal contribution of that emission unit to the enhancement of political capital value. Comparing to equation (5), we see that the evolution of the shadow value of pollution matches that of the previous setting only if $\partial I/\partial Z = P = 0$, which must then imply $I = 0$ as well – *i.e.* there is no lobbying. If lobbying occurs, so that political capital is developed, then the time rate of change in η_Z exceeds that of θ; this implies that the shadow value is smaller in magnitude relative to the absence of lobbying. But then equation (17) tells us the optimal tariff is less than the value that would obtain in the absence of lobbying.[23]

Equation (19) tells us that the rate of change of the shadow value of political capital for the Downstream government is given by the opportunity cost of holding on to a unit of political capital, marginal benefits received by the Downstream government from that unit, and the marginal contribution of that unit to the political capital value.

The system (17)-(19) illustrates how the accumulation of political capital translates into the influence of the Upstream country's government over the Downstream authority's decisions. Now, as the Downstream policymaker derives additional utility from political contributions, she realizes the shadow price of the political capital stock, representing the marginal utility she would give up if one less unit of political capital was available. This information is being used by the Downstream authority in formulating the Markov perfect strategy: equation (18) implies that the dynamics of the shadow price of pollution is conditioned on the shadow price of political capital for the Downstream government. Comparison between equation (5), representing the evolution of the shadow price of pollution in the simple version of the model, and equation (18), showing the time path of the pollution co-state variable in the presence of international lobbying, demonstrates that political capital investment affects the evolution of the shadow price of pollution in the Downstream country. In turn, this alters the time path of the optimal tariff, as indicated by equation (17).

[23] This, of course, is the whole point of the lobbying efforts in the first place.

This class of linear-quadratic differential games has equilibrium strategies that are linear in state variables:

$$\tau(Z,P) = \alpha_1 + \alpha_2 Z - \alpha_3 P; \tag{20}$$

$$I(Z,P) = \gamma_1 + \gamma_2 Z - \gamma_3 P. \tag{21}$$

Presumably, the parameters α_2 and α_3 in the downstream player's strategy are both positive: as in the preceding section, higher pollution stocks raise the incentive to assess a tariff, while the whole point of political lobbying is to effect lower tariffs. With respect to the upstream player's strategy, the incentive to lobby is presumably larger when higher tariffs are in the cards, which suggests that γ_2 is positive. In part because of this indirect effect, and in part because of the diminishing marginal impact of the capital stock upon downstream incentives, one infers that that γ_3 is also positive.

Upon combining equations (1), (14), (20) and (21), we may rewrite the state equations for pollution and political capital as:

$$\dot{Z} = E^0 - \lambda\alpha_1 - (\lambda\alpha_2 + k)Z + \lambda\alpha_3 P; \tag{22}$$

$$\dot{P} = \gamma_1 + \gamma_2 Z - (\delta + \gamma_3)P. \tag{23}$$

It is easy to see that the solution to the system (22) – (23) is a pair of exponentials; specifically, the solution is given by the sum of a particular solution, (Z^{MP}, P^{MP}), and the general solution to the system of homogenous differential equations

$$\dot{Z} = -(\lambda\alpha_2 + k)Z + \lambda\alpha_3 P; \tag{24}$$

$$\dot{P} = \gamma_2 Z + (\gamma_3 - \delta)P. \tag{25}$$

The solution to this latter system is of the form (Z, P) = ($\nu e^{\sigma t}$, $\mu e^{\sigma t}$). Inserting these functions into equations (24) and (25) leads to the characteristic equation

$$(\sigma + \lambda\alpha_2 + k)(\sigma + \delta - \gamma_3) - \lambda\alpha_3\gamma_2 = 0, \tag{26}$$

which the parameter σ must satisfy. Denote the roots of this equation by σ_1 and σ_2, with σ_1 the smaller root. It is straightforward to see that $\sigma_1 < \min\{-(\lambda\alpha_2 + k), -(\gamma_3 + \delta)\}$ and $\sigma_2 > \max\{-(\lambda\alpha_2 + k), -(\gamma_3 + \delta)\}$; accordingly, σ_1 is negative while σ_2 could be either negative or positive. The state variables are subject to transversality conditions that ensure they converge to a steady state; it follows that the solution is $(Z_g, P_g) = (\nu_1 e^{-\sigma_1 t}, \mu_1 e^{-\sigma_1 t})$ if $\sigma_2 > 0 > \sigma_1$, and $(Z_g, P_g) = (\nu_1 e^{-\sigma_1 t} + \nu_2 e^{-\sigma_2 t}, \mu_1 e^{-\sigma_1 t} + \mu_2 e^{-\sigma_2 t})$ if $0 > \sigma_2 > \sigma_1$.

The particular solution is found by setting $\dot{Z} = 0 = \dot{P}$ in equations (22) and (23), and then solving the resultant system of two equations. By construction, then, the particular solution corresponds to the pair of steady state values for the two state variables:

$$Z^{MP} = [(\delta - \gamma_3)(E^0 - \lambda\alpha_1) + \lambda\alpha_3\gamma_1]/[(\lambda\alpha_2 + k)(\delta + \gamma_3) - \lambda\alpha_3\gamma_2]; \tag{27}$$

$$P^{MP} = [\gamma_2(E^0 - \lambda\alpha_1) + \gamma_1(\lambda\alpha_2 + k)]/[(\lambda\alpha_2 + k)(\delta + \gamma_3) - \lambda\alpha_3\gamma_2]. \tag{28}$$

We note for later reference that $P^{MP} > 0$. Altogether, the complete solution can be written as

$$Z(t) = \nu_1 e^{-\sigma_1 t} + \nu_2 e^{-\sigma_2 t} + Z^{MP}, \tag{29}$$

$$P(t) = \mu_1 e^{-\sigma_1 t} + \mu_2 e^{-\sigma_2 t} + P^{MP}, \tag{30}$$

where $\nu_2 = 0 = \mu_2$ if $\sigma_2 > 0$. Upon time-differentiating the right-hand side of equations (29)-(30), and combining with equations (24)-(25), one may derive two expressions for $\frac{\nu_1}{\mu_1} = h_1$: it equals both $\frac{\lambda\alpha_2 + k + \sigma_1}{\lambda\alpha_3}$ and $\frac{\gamma_2}{\sigma_1 + \gamma_3 + \delta}$. We note that $h_1 < 0$, since $\sigma_1 < \min\{-(\lambda\alpha_2 + k), -(\gamma_3 + \delta)\}$. If in addition $\sigma_2 < 0$, one may also derive two expressions for $\frac{\nu_2}{\mu_2} = h_2$: it equals both $\frac{\lambda\alpha_2 + k + \sigma_2}{\lambda\alpha_3}$ and $\frac{\gamma_2}{\sigma_2 + \gamma_3 + \delta}$. We note that $h_2 > 0$, since $\sigma_2 > \max\{-(\lambda\alpha_2 + k), -(\gamma_3 + \delta)\}$.

Using these proportionality coefficients, the formulae for the state variables may be rewritten as

$$Z(t) = \nu_1 e^{\sigma_1 t} + \nu_2 e^{\sigma_2 t} + Z^{MP}, \tag{31}$$

$$P(t) = h_1 \nu_1 e^{\sigma_1 t} + h_2 \nu_2 e^{\sigma_2 t} + P^{MP}. \tag{32}$$

As these expressions must hold at t = 0, one obtains a system of two equations for the coefficients (ν_1, ν_2); the solution of this system then yields:

$$\upsilon_1 = {[h_2(Z_0 - Z^{MP}) + P^{MP}]}\Big/{(h_2 - h_1)}; \tag{33}$$

$$\upsilon_2 = {-[h_1(Z_0 - Z^{MP}) + P^{MP}]}\Big/{(h_2 - h_1)}. \tag{34}$$

Combining equations (31)-(34), together with the definitions for the proportionality coefficients h_1 and h_2, then completes the solution for (Z, P). Finally, upon substituting the solution for (Z, P) into equations (20) and (21) we obtain the Markov perfect equilibrium strategies, each of which can be expressed as the sum of a linear combination of exponentials and a constant. Because the exponentials all have negative exponents, the constants must be the steady state values for tariff and political investment. Alternatively, these steady state values are easily calculated from the state equations as

$$\tau^{MP} = (E^0 - kZ^{MP})/\lambda; \tag{29}$$

$$I^{MP} = \delta P^{MP}. \tag{30}$$

The expressions for the control variables τ and I, and the state variables, Z and P, all depend on the six parameters in the Markov strategies given in eqs. (20) – (21). These coefficients can be pinned down by appealing to the optimality conditions, as we show in Appendix B.

It is straightforward, but tedious, to show that both the stock of pollution and the stock of political capital rise from their initial levels to the steady state values, assuming that $Z_0 < Z^{MP}$. We summarize the foregoing discussion in the next proposition, which describes the Markov perfect equilibrium, along with the monotonicity properties of the time paths for pollution and political capital.

PROPOSITION 2 *There exists a pair of linear feedback strategies that constitutes an asymptotically stable Markov perfect equilibrium (stable node) that results in a steady state pollution stock* Z^{MP} *and steady state pollution stock* P^{MP}*, as given by equations (27) and (28), respectively. If the initial levels of pollution and political capital are small, both the pollution stock and political capital stock rise from the initial level to the steady state level.*

Proof. Previously demonstrated.

The optimal solution paths for the stock of pollution and political capital are depicted graphically in Figure 2. In general, our model would require construction of a four-variable phase diagram to illustrate the convergence of the system to the Markov perfect equilibrium. But in view of the fact that both the optimal tariff and investment paths are linearly dependent on $\dot{Z}$ and $\dot{P}$, we are able to reduce the representation of our four-dimensional equilibrium to a two-dimensional phase diagram. Figure 2 displays a unique and stable equilibrium, and the directions of phase trajectories suggest that the time paths of political capital and pollution stocks are determined by their initial levels. If the initial levels of the stocks are sufficiently far away from the long run equilibrium, the streamlines never venture beyond a single phase space region, and both the stocks monotonically ascend to the steady state.[24]

[Figure 2 here]

[24] By contrast, if the initial value of either stock is sufficiently close to the respective steady state level, the streamlines will cross over from one phase space region onto another, showing that the direction of movement of this stock will change along its evolution path.

4. The Implications of Lobbying

In this section we explore the implications of introducing lobbying into the model. Intuitively, one expects this extension will influence the evolution of Downstream's behavior, a prediction that our first result confirms.

PROPOSITION 3 *If the Upstream country's Markov-perfect strategy has $\gamma_2 > 0$ and $\gamma_3 < 0$, then the steady state tariff is smaller and the steady state pollution stock is larger in the variant of the model where lobbying can occur than when lobbying cannot occur.*

Proof. Suppose $Z_0 = Z^e$ and that, initially, $I = P = 0$; then $\tau = \tau^e$. By Proposition 2 the steady state value of P is positive in the variant of the model where lobbying can occur. Therefore, there must be an interval where $I > 0$. But then equations (17)-(19) imply τ must fall, and Z must rise; ultimately, the new rest point must have smaller tariff and larger pollution stock than the original combination. That is, $\tau^{MP} < \tau^e$ and $Z^{MP} > Z^e$. Q.E.D.

Proposition 3 demonstrates how political factors such as foreign lobbying can lead to less stringent regulations of the transboundary pollution externality in the long-run. If the Upstream country brings international political capital into play, it is capable of increasing the magnitude of the steady state shadow price of pollution for the Downstream authority and thus achieving a lower tariff rate in the long-run, which favors Upstream's welfare. Lower equilibrium tariff leads to a higher level of combined emissions in the long run and, consequently, to exacerbation of the environmental problem.

Because the tariff path selected in the absence of lobbying maximizes the present discounted value of the flow of welfare for a typical downstream citizen, it follows that lobbying exerts a negative effect on this citizen's welfare. The Downstream government is inclined to follow such a course of action because it values the political stock lobbying creates, despite the fact this stock is not important to its citizenry. On the other hand, the flow of information associated with lobbying expenditures can provide benefits to the citizenry. Accordingly, there is a tension between the short-term benefits (from information) and the costs associated with the distorted tariff path that arises.

Higher values of f indicate the Downstream policymaker's willingness to set the tariff rate that diverges from the social welfare-maximizing level in return for political contributions. This 'marginal utility' can be interpreted as an indicator of the level of corruption in the Downstream government or susceptibility of the Downstream authority to the international political influence. The level of corruption is reflected by the government's willingness to allow Upstream's lobby to influence its policy, i.e., the propensity to sell policies for personal gains in the form of monetary transfers. The latter interpretation is in line with Gunter Schulze and Heinrich Ursprung (2001), who note that in the political-economic models of trade and environment political contributions influence government policy, not the election outcome. But there is a further, and potentially offsetting, effect that derives from the potential informational benefits associated with Upstream's lobbying efforts.

In order to examine long-run welfare implications of foreign lobbying, consider first the two countries in the neighborhood of the steady state of our reference scenario presented in the section 2, where the Upstream country does not engage in foreign lobbying and the Downstream government determines the tariff rate by maximizing her constituents' welfare.[25] After the steady state is reached, the Downstream country's social welfare is given by $W_d(\tau^e)\text{-}sZ^e$ and the Upstream country's social welfare is given by $W_u(\tau^e)$, where τ^e is the Downstream citizens'

[25] While we realize that the welfare transition path to the long-run equilibrium is interesting, it is intractable without resorting to numerically specified functions. Therefore we are focusing on the comparison of the steady states.

welfare maximizing long-run level of the tariff, and Z^e is the corresponding steady state level of pollution. Then suppose the Upstream government is able to engage in foreign lobbying for a lower tariff; Proposition 2 illustrates the existence of the interior solution where the steady state investment rate is positive. Then similarly to the revealed preference argument, we can infer that political investment allows the Upstream government to increase her country's long-run welfare level, since otherwise she would choose a zero investment rate.

The analysis for the Downstream country is more complicated. On the one hand, the tariff which maximizes the presented discounted flow of utility less pollution damages is maximized at τ^e; since $\tau^{MP} < \tau^e$ it follows that the presence of foreign lobbying lowers this aspect of downstream payoffs (*i.e.*, $W_d(\tau^{MP})$-sZ^{MP} < $W_d(\tau^e)$-sZ^e). The magnitude of this loss depends on the degree to which the steady state tariff is lowered by lobbying; comparing eqs. (4) and (17) it is evident that this reduction is proportional to the difference between the steady state shadow prices with and without lobbying, $\eta_Z^e - \theta^e$. As we noted earlier, $-\theta^e$ corresponds to the present discounted value of marginal pollution damages. Returning to eq. (18), we see that the shadow price of pollution when there is lobbying is smaller in magnitude (closer to zero) than the present discounted value of marginal pollution damages positive influence exerted by the shadow value of political capital. In turn, this shadow value, as well as the steady state value of I, depends on the marginal value (to the downstream decision-maker) of political capital, $F'(P)$. Thus, the welfare impact on downstream citizens reflects a tension between the marginal information benefits β and the marginal political benefits f. We summarize these remarks in the following proposition.

PROPOSITION 5 *If the Upstream authority engages in foreign lobbying for a lower tariff, then social welfare of the Upstream country increases. Net benefits for downstream citizens can rise or fall, depending on the relative magnitude of β and f.*

5. Concluding Remarks

Pollution often does not respect political boundaries; in many cases, several countries are concerned with and affected by environmental degradation. Regulation of unidirectional transboundary externalities is particularly problematic when damages are asymmetric, and some countries are unaffected or less affected by the externality than other countries. In such cases, trade policies can be both a "second best" tool to control the problem and a mechanism to encourage cooperation between upstream and downstream countries. This paper improves our understanding of both aspects of trade policy role in transboundary externalities regulation by allowing for transboundary stock pollutants and international political lobbying.

While unidirectional transboundary stock pollutants, which encompass important real world examples such as acid rain and water pollution, are of substantial interest for international environmental policymaking, they have been largely ignored in the extant literature. Our results show that an atemporal import tariff alone cannot be an optimal response to the transboundary externality. Instead, at every point in time, the optimal tariff is determined by the current level of accumulated pollution as it adjusts to the endogenous changes in the pollution stock: if the stock of pollution increases, so does the tariff. Such endogenous tariff determination can be seen as the "good news" for the use of trade policy as a regulation tool for transboundary pollution problems.

It has been suggested that trade measures may serve as one of the plausible ways to modify the behavior of the upstream government and to stimulate international cooperation. In the context of our model, this could imply that the Upstream country has an incentive to engage in pollution abatement to deter the Downstream country from imposing more severe tariffs in response to the rising pollution stock. But these same concerns also create an incentive for the Upstream country to engage in activities that would negatively affect the externality regulation, such as lobbying the Downstream government to lower its tariffs. Failure to identify and consider such an incentive can lead to misleading conclusions regarding the effectiveness of trade policy in promoting cooperation between the countries linked by the unidirectional pollution externality. We show that if the government of the Downstream country is susceptible to foreign political influence, then the Upstream authority finds it optimal to maintain a positive steady state level of investment lobbying capital to influence the Downstream authority's policy choice. As a result of such foreign lobbying, Downstream country's tariff policy can diverge from its socially optimal path, and this divergence from optimal pollution regulation depends on the degree of corruptibility of the Downstream authority. Consequently, foreign lobbying leads to the degradation of environmental quality, and the distortions caused by corruption and foreign lobbying increase the Upstream country's social welfare but decrease welfare in the Downstream country.

Our findings suggest that the usefulness of trade policy as an instrument for promoting cooperation and internalizing transboundary externalities depends critically on the degree of governments' susceptibility to foreign political influence as well as their corruptibility. Essentially, foreign lobbying offers the upstream government an alternative to environmental regulation and abatement if it is trying to lower the tariff imposed by the Downstream country. As noted in Kee et al. (2004, pp. 3-4), foreign lobbying is a high return activity, and may therefore provide a cheaper alternative to the administrative costs of implementation and monitoring of environmental regulations. When the Downstream authority is susceptible to such political influence, the potential for trade measures to encourage international cooperation in regulating the externality can be sharply reduced. Given that corruption exists in all countries (Ramon Lopes and Siddhartha Mitra 2000, pp. 138-39), at least to some degree, this result is the "bad news" for the usefulness of trade policy as an indirect tool for regulating transboundary pollution. That point noted, the news is not necessarily bad: because lobbying can generate a flow of information, the associated benefits must be compared against the sots linked to the adjusted tariff. If the marginal benefit of information is large, or the distortion in tariff is small, the net effect need not be deleterious.

While our results show the importance of including political economy considerations in the trade and environmental policy discussion, we have only considered one aspect of political lobbying. It would be interesting to consider lobbying by other special-interest groups, such as domestic producers in the downstream country seeking higher level of protection or consumer interest groups. Allowing for such additional political lobbying could yield interesting results, and may therefore represent a fruitful line of further inquiry.

Appendix A: Comparative Dynamic Effects

The proof of Proposition 1 shows that $h = \frac{\kappa_{\tau 1}}{\kappa_{Z1}} = -\frac{(\rho_1 + k)}{\lambda}$, where ρ_1 is the negative root to the characteristic equation (9):

$$(\rho - r - k)(\rho + k) - \frac{\lambda^2 s}{b(1-A^2)} = 0,$$

so that

$$\rho_1 = \frac{1}{2}\{r - \sqrt{(r+2k)^2 + 4\lambda^2 s/[b(1-A^2)]}\}. \tag{A1}$$

It is then straightforward to show that $\partial\rho_1/\partial s < 0$, so that $\partial h/\partial s > 0$. The expression for h can be rewritten as $\rho_1 = -(k + \lambda h)$; inserting this into the characteristic equation then yields

$$\left(h + \frac{r+2k}{\lambda}\right) h = \frac{s}{b(1-A^2)}. \tag{A2}$$

For a parametric change in r, k, or λ the right side of (A2) is constant, and so the left side must not change. From this observation it follows that h falls with an increase in either r or k, or a decrease in λ.

Appendix B: Deriving the Coefficients in the Markov Strategies

Time-differentiating the optimality condition (14), using equation (14) to substitute for ξ_P and equation (16) to substitute for $\dot{\xi}_P$, we obtain

$$\dot{I} = (r + \delta - \lambda\alpha_3)I - \alpha_3(Y_0 - b(1-A)\tau). \tag{A3}$$

Next, time-differentiate the right-hand side of equation (21) to express the left-hand side of (A3) in terms of $\dot{Z}$ and $\dot{P}$, and use equations (20) and (21) to write I and τ in terms of Z and P. Then use equations (31) and (32) to express Z and P (and $\dot{Z}$ and $\dot{P}$) in terms of the exponentials $e^{\sigma_1 t}$ and $e^{\sigma_2 t}$. This procedure then produces three restrictions, corresponding to the constant and slopes on the exponential terms; the restriction on the constant corresponds to eq. (A4), while the other two imply

$$(\sigma_1 - r - \delta + \lambda\alpha_3)(\gamma_2 - \gamma_3 h_1) = \alpha_3[AY_0 - b(1-A)](\alpha_2 - \alpha_3 h_1) \, ; \qquad \text{(A5)}$$

$$(\sigma_2 - r - \delta + \lambda\alpha_3)(\gamma_2 - \gamma_3 h_2) = \alpha_3[AY_0 - b(1-A)](\alpha_2 - \alpha_3 h_2) \; . \qquad \text{(A6)}$$

To analyze the Downstream player, we time-differentiate the optimality condition, here equation (17), and then use equation (18) to substitute for $\dot{\eta}_Z$ and equation (17) to substitute for η_Z. This allows us to express $\dot{\tau}$ in terms of τ, Z, P, I and η_P:

$$\dot{\tau} = (r+k)(\tau - \tfrac{AY_0}{b(1-A^2)}) - \tfrac{\lambda}{b(1-A^2)}(sZ - \gamma_2(\beta I + \eta_P)). \qquad \text{(A7)}$$

To eliminate η_P from this expression we time-differentiate equation (A7), use equation (19) to substitute for $\dot{\eta}_P$ and equation (A7) to substitute for η_P. In this manner, we derive an expression involving $\ddot{\tau}, \dot{\tau}, \tau, \dot{Z}, \dot{P}$ and $\dot{I}$:

$$\ddot{\tau} = (r+k+\gamma_3+r+\delta)\dot{\tau} - \frac{\lambda}{b(1-A^2)}\left[s\dot{Z} - \gamma_2\beta\left(\dot{I} - (r+\delta)I\right)\right] +$$

$$(\gamma_3 + r + \delta)\left\{(r+k)\left(\tfrac{AY_0}{b(1-A^2)} - \tau\right) + \tfrac{\lambda s Z}{b(1-A^2)}\right\}. \qquad \text{(A8)}$$

Then using equations (30) and (31) we obtain an expression involving a combination of the exponentials $e^{\sigma_1 t}$ and $e^{\sigma_2 t}$. As this expression must hold for all values of t we obtain three restrictions by comparing coefficients:

$$\tfrac{-\lambda\gamma_2\beta(r+\delta)\gamma_1}{b(1-A^2)} + (\gamma_3 + r + \delta)[(r+k)\left\{\left(\tfrac{AY_0}{b(1-A^2)} - \alpha_1\right) + \tfrac{\lambda}{b(1-A^2)}\left(s\hat{Z}^e + f_1\hat{P}^e\right)\right\} = 0; \quad \text{(A9)}$$

$$(\alpha_2 - \alpha_3 h_1)[\sigma_1{}^2 - \sigma_1(r+k+\gamma_3+r+\delta) + (\gamma_3+r+\delta)(r+k)] =$$

$$(\gamma_2 - \gamma_3 h_1)[\sigma_1 - (r+\delta)]\tfrac{\lambda\beta\gamma_2}{b(1-A^2)} - [\sigma_1 - (r+\delta)]\tfrac{s\lambda}{b(1-A^2)} \, ; \qquad \text{(A10)}$$

$$(\alpha_2 - \alpha_3 h_1)[\sigma_2{}^2 - \sigma_2(r+k+\gamma_3+r+\delta) + (\gamma_3+r+\delta)(r+k)] =$$

$$(\gamma_2 - \gamma_3 h_1)[\sigma_2 - (r+\delta)]\tfrac{\lambda\beta\gamma_2}{b(1-A^2)} - [\sigma_2 - (r+\delta)]\tfrac{s\lambda}{b(1-A^2)} \, . \qquad \text{(A11)}$$

Appendix C

Proof of Proposition 3

Since we consider both characteristic roots $_1$ and $_2$ to be negative, it entails that the determinant of the Jacobian matrix of the system, $\left|J_E\right| = (\quad _2 + k)(\, _3 + \quad) \qquad _3 \, _2 > 0$ and the trace of this Jacobian matrix, $trJ_E = \quad (\quad _2 + k) \quad (\, _3 + \quad) < 0$. It is straightforward to show that $(trJ_E)^2 > 4\left|J_E\right|$, thus the obtained Markov perfect equilibrium is a stable node.[26]

$$P(t) = a_1 a_2 \frac{Z_0 \quad Z^{MP}}{a_2 \quad a_1}(e^{\,_1 t} \quad e^{\,_2 t}) \quad \frac{P_0 \quad P^{MP}}{a_2 \quad a_1}(a_1 e^{\,_1 t} \quad a_2 e^{\,_2 t}) + P^{MP} \qquad (9)$$

Substitution of xxx and (9) into equations will yield the expressions for optimal time paths for the tariff and investment strategies.

Assume the opposite and let the steady state tariff chosen by the Downstream government be higher in the presence of foreign lobbying:

$$^{MP} \qquad ^{e}. \qquad (10)$$

Since emissions are decreasing with tariff, we can write that

$$E(\;^{MP}) \quad E(\;^{e}).$$

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[26] $(trJ_E)^2 \quad 4\left|J_E\right| = (\quad _2 + k)^2 + (\, _3 + \quad)^2 + 2(\quad _2 + k)(\, _3 + \quad) \quad 4(\quad _2 + k)(\, _3 + \quad) + 4 \qquad _3 \, _2$

$= [(\quad _2 + k) \quad (\, _3 + \quad)]^2 + 4 \qquad _3 \, _2 > 0$

It is then clear from equations that $Z^{MP} \quad Z^{e}$. Given that the damage function, *D(Z)*, is increasing and strictly convex, it follows that

$$D(Z^{MP}) \quad D(Z^{e}),$$

and therefore

$$\frac{D(Z^{MP})}{r+k} \quad \frac{D(Z^{e})}{r+k},$$

or equivalently

$$^{MP} \quad ^{e}. \qquad (11)$$

If $I(Z^{MP}, P^{MP}) / Z > 0$ and $I(Z^{MP}, P^{MP}) / P < 0$, equation Erreur ! Source du renvoi introuvable. implies that

$$\frac{{}_{P}^{MP} \; I(Z,P) / Z}{r+k} > 0. \qquad (12)$$

Combining inequalities (11)-(12) with equation Erreur ! Source du renvoi introuvable., we can infer that

$$_{Z}^{MP} > \; ^{e}.$$

In light of Lemma, it then follows from equations (4) and Erreur ! Source du renvoi introuvable. that

$$^{MP} < \; ^{e},$$

which says the opposite to our initial assumption (10). Hence Proposition 3 is proved by contradiction.

Proof of Proposition 5

A first-order linear differential equation system produces the following solution paths for the pollution stock and political capital stock, respectively:

In order to explore monotonicity properties of the time paths for pollution and political capital, time differentiate Erreur ! Source du renvoi introuvable. and (9):

$$Z(t) = \frac{Z_0 \quad Z^{MP}}{a_2 \quad a_1}(a_2 \;{}_1 e^{{}_1 t} \quad a_1 \;{}_2 e^{{}_2 t}) \quad \frac{P_0 \quad P^{MP}}{a_2 \quad a_1}(\;{}_1 e^{{}_1 t} \quad {}_2 e^{{}_2 t}) \tag{13}$$

$$P(t) = a_1 a_2 \frac{Z_0 \quad Z^{MP}}{a_2 \quad a_1}(\;{}_1 e^{{}_1 t} \quad {}_2 e^{{}_2 t}) \quad \frac{P_0 \quad P^{MP}}{a_2 \quad a_1}(a_1 \;{}_1 e^{{}_1 t} \quad a_2 \;{}_2 e^{{}_2 t}) \tag{14}$$

It is clear from equations (13) and (14) that each of the functions *Z(t)* and *P(t)* may have only one extremum, i.e., there may exist only one value of *t,* $t = \tilde{t}$, that sets $Z(t)$ equal to zero and only one value of *t,* $t = \hat{t}$, that sets $P(t)$ equal to zero, and where these derivatives change their signs. It then follows that if the initial stock of pollution, $Z(0) = Z_0$, is below the steady state level, Z^{MP}, and $Z(0) \quad 0$, we can conclude that *Z(t)* rises monotonically from its initial level to the steady state. Using equation (13), we can rewrite $Z(0) \quad 0$ condition as

$$\frac{Z_0 \quad Z^{MP}}{P_0 \quad P^{MP}} \quad \frac{{}_1 \quad {}_2}{a_2 \;{}_1 \quad a_1 \;{}_2}, \tag{15}$$

where if the non-negativity constraint is binding, function $Z(t)$ reaches its minimum at the time $t = 0$. Upon substitution of expressions Erreur ! Source du renvoi introuvable. and Erreur ! Source du renvoi introuvable. for a_1 and a_2 into condition (15), we find that (15) is equivalent to

$$\frac{Z_0 \quad Z^{MP}}{P_0 \quad P^{MP}} \quad \frac{{}_3}{{}_2 + k} \tag{16}$$

Condition (16) says that the line connecting the initial point (Z_0, P_0) and the steady state equilibrium point (Z^{MP}, P^{MP}) is at least as steep as the $\dot{Z} = 0$ isocline. Thus it implies that if the initial stock of pollution, Z_0, is sufficiently less than the steady state pollution stock, Z^{MP}, then pollution will rise monotonically to the steady state level. However, if we start with Z_0 that is fairly close to the steady state pollution level then the stock of pollution will initially fall but starting with the time $\tilde{t}$ it will rise monotonically to Z^{MP}.

Similarly, considering the case where the initial political capital stock is below its steady state level, we can argue that if $P(0) \quad 0$ then $P(t)$ grows monotonically from its initial level, P_0, to its steady state value, P^{MP}. Using equation (14), this condition can be formalized as

$$\frac{Z_0 \quad Z^{MP}}{P_0 \quad P^{MP}} \quad \frac{a_1 \; {}_1 \quad a_2 \; {}_2}{a_1 a_2 (\; {}_1 \quad {}_2)}, \tag{ 17}$$

where binding non-negativity constraint implies that function $P(t)$ has a minimum point at the time $t = 0$. Substitution of expressions Erreur ! Source du renvoi introuvable. and Erreur ! Source du renvoi introuvable. yields the following condition:

$$\frac{Z_0 \quad Z^{MP}}{P_0 \quad P^{MP}} \quad \frac{{}_3 +}{{}_2} \tag{ 18}$$

Condition (18) states that the $\dot{P} = 0$ isocline is at least as steep as the line connecting the initial point with the steady state point. It suggests that if the initial stock of political capital, P_0, is sufficiently below its steady state level, P^{MP}, then the stock of political capital rises monotonically to P^{MP}. Conversely, if P_0 is rather close to the steady state political capital level, then the stock of political capital will go down initially, but then starting at time $\hat{t}$ it will increase monotonically to P^{MP}.

Since stability of the characterized Markov perfect equilibrium requires $(\quad {}_2 + k)(\; {}_3 + \quad) \qquad {}_3 \; {}_2 > 0$, it follows that the slope of the $\dot{Z} = 0$ isocline, $\; {}_3 /(\quad {}_2 + k)$, is less than the slope the $\dot{P}=0$ isocline, $(\ _3 + \ )/\ _2$. Therefore, both Z and P will rise monotonically from the initial level to the steady state if

$$\left.\frac{dZ}{dP}\right|_{\dot{Z}=0} \quad \frac{Z_0 \quad Z^{MP}}{P_0 \quad P^{MP}} \quad \left.\frac{dZ}{dP}\right|_{\dot{P}=0}, \tag{19}$$

that is if both the initial levels of Z and P are sufficiently below their equilibrium levels.

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