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Essays on the Design of Environmental Policy

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Essi Eerola

Contents

Introduction

1 Background

The main purpose of environmental policy is to correct externalities caused by production or consumption. This is done by using appropriate taxes or subsidies or other methods of regulation. If lump sum transfers were available, that is, if income could be transferred without any cost from one group of individuals to another, the objective of a given policy could be reached without redistribution of well-being within the society.

However, typically such transfers are not available. Consequently, it is not possible to separate the objective of environmental policy and the redistributional effects of actions taken to achieve it. In this situation, groups that are severely affected by environmental policy may seek to increase their welfare not only by influencing pure redistribution itself, but also by pushing the objective of environmental policy to their favor. In order to understand what objectives can be achieved, given the rules of the decision making process and the policy instruments available, it is therefore necessary to take the distributional issues into account.

Nature conservation is a good example of an environmental issue where people have very different preferences over the government's decisions. Forests, for instance, yield important private benefits for their owners in terms of timber and related products. In addition, forest resources provide global public goods in the form of stores for carbon and biodiversity. They also provide local public goods like benefits from reduced erosion, positive amenity values for local residents, and increased tourism. These private and public uses of forest resources are usually in conflict. Thus, if the forest owner is not compensated for the external benefits created by the forestry, the level of the public services provided by the forests may remain too low. The aim of a government

intervention in the form of forest policy is to create a balance between these different objectives. Typically people are heterogenous in that not all own forests or shares of timber using firms, and not all use forests for recreation. The resulting divergence of preferences is seen as political debates on what is the 'correct' objective of forest policy.

The relevant conflict of interests may also exist at the international level. This is self-evident when one considers, for instance, pollutants that the wind carries across national borders. However, the conflict of interests may be equally present when the link between the well-being of individuals in different countries or jurisdictions exists through the markets. An often expressed concern is that, in the hope to attract capital and jobs, national governments will relax environmental standards. A regulatory competition between the governments could then lead to national environmental policies being distorted in favor of the domestic producers, a phenomenon often referred to as environmental or ecological dumping.

This concern has become more widespread because of the intensified interdependence of national economies and the rapid increase in the number and importance of multinational firms. Multinational enterprises have production facilities in more than one country and are thus seen to be in a more favorable position than national firms because they can react more efficiently to changes in national policy making. When faced with tightening emission taxation, multinational firms, unlike national firms, are able to shift production from one country to another so as to escape higher tax rates.

The emergence of multinational production not only shapes national policy design but also depends on the international institutional setting and national policies. For instance, during the last few decades, international free trade agreements have reduced the possibility of individual governments to use direct trade policy measures like import tariffs and barriers to investment. This tendency may have a direct impact on multinational production. In addition, restrictions in one area of policy design are likely to affect policy making in other areas, like in the field of environmental policy that has largely remained at the discretion of national governments. To the extent that this kind of changes in the international regime cause shifts in environmental policies, they may also change the optimal strategies of polluting firms.

In my thesis, I analyze in detail the issues discussed above. In all the cases, the welfare distributing effects of environmental policy are taken into account and the

agents may take actions to influence policy making. The main question of interest is how the policy outcome is shaped by the interaction of agents and how it depends on the prevailing institutional setting. By comparing the outcome to policies that are, in some sense, socially optimal, one can then also identify the sources of inefficiencies in actual policy making.

In the first essay of the thesis, I study the formation of forest conservation policy in a situation where a conflict of interests exists between the wood processing industry, environmentalists, and consumers. In the second and third essay, the main conflict of interests is at the international level. The second essay studies the implications of regulatory competition between national governments on national environmental policies when polluting firms are multinational. The third essay, in turn, examines the influence of international free trade agreements on the attractiveness of multinational production when environmental policy is at the discretion of national governments.

The second section of this introductory essay presents the main findings of the literature relevant to this thesis. The third section summarizes the three essays of the thesis.

2 Related Literature

This section surveys the relevant literature and locates my research problems in that context. The section is divided into two subsections. The first subsection focuses on the literature on special interest politics with an emphasis on the design of environmental policy and the second on the literature on environmental policy in international setting.

2.1 Special Interest Politics

Successful lobbying is a public good from the point of view of any politically active group. Based on this observation Olson argued in his famous book "The Logic of Collective Action" (1965) that small groups and groups that are able to provide private benefits to their members are most successful in influencing policy making. The first attempt to approach the issue of why environmental policy would reflect the interests of some well-specified groups in the society can be attributed to the public choice

theorists Buchanan and Tullock (1975). They claimed that the so-called command-and-control instruments are widely used because they are preferred by the polluting firms. Buchanan and Tullock considered two alternative ways to restrict emissions, namely a unit tax on output and an equal output reduction on all existing firms. Their argument was that the firms prefer output restrictions to taxes because a tax imposes short-run losses to the firms whereas an output restriction may yield cartel-like gains because it effectively grandfathers pollution rights to existing firms. Their paper stimulated an extensive literature seeking to determine in what way polluting firms are affected by different instruments of environmental policy. See e.g. Yohe (1976), Maloney and McCormick (1982), Dewees (1983), and Hahn (1990). Leidy and Hoekman (1994) extend the analysis of Buchanan and Tullock to an open economy with trade barriers and consider explicitly also the interests of environmentalists and labor groups. Following the work of Buchanan and Tullock, the prominent question was why polluting industry should prefer one type of regulation over another, and in particular, why it should prefer inefficient methods of regulation. See e.g. Coate and Morris (1995) and references therein.

A different question is how exactly this preference would translate into political influence. At least since the influential book "The Economic Analysis of Democracy" (1957) by Downs, the answer has often been based on the following ideas: First, voters are generally poorly informed about the characteristics of politicians and their actions. In the words of Downs, voters remain rationally ignorant as information collection is costly and the possible influence of each individual voter on the outcome of a large election is negligible. Second, politicians care for re-election. Since the voters are poorly informed, the candidates for political office need to spend resources in order to convince the voters of their abilities. This gives rise to a situation where interest groups working on a specific policy issue are able to influence policies either by influencing policy making directly or by trying to ensure that the 'right' candidate is elected to office.

Two approaches focusing on these different aspects of lobbying have been taken in the literature.[1] The first approach concentrates on elections and studies the electoral competition between candidates or parties in the presence of campaign contributions

[1]For recent work combining these two approaches, see e.g. Aidt and Dutta (2001), Besley and Coate (2001) and Grossman and Helpman (1996).

from interest groups. The interest groups have two motives for giving campaign contributions. First, they may give contributions in order to induce the candidate or party to choose a more favorable policy position. Second, they may seek to influence the electoral success of their favorite candidate. Typically, the behavior of voters is not explicitly modelled, but the voters provide a link between the political campaign and the expected electoral success.[2] Each candidate chooses his policy position so as to maximize the campaign contributions and thus the probability of winning. This approach could be seen as a formalization of Downs' idea that "parties formulate policies in order to win elections rather than win elections in order to formulate policies". See e.g. Hillman and Ursprung (1994) for an application to trade policy where two parties compete in an election and receive contributions from environmentalists and domestic as well as foreign industry.

The other approach is to abstract from the election competition and analyze the policy decisions of an incumbent government under the influence of lobbying. The origins of this approach can be traced back to important papers by Stigler (1971) and Peltzman (1976). One central ingredient of this approach has been the notion of regulatory capture reflecting the idea that concentrated special interests can influence policies to such a large extent that policy making can be seen as captured by them. Some studies concentrate on the competition between interest groups and interpret politicians as taking actions solely determined by the pressure of the interest groups. See e.g. Becker (1983). Others, in turn, focus more on the decision making process of the incumbent. For an application to environmental policy, see e.g. Rauscher (1997) who analyzes equilibrium policies when the government has a rich set instruments available. For a survey see e.g. Mueller (1989, 1997) or Persson (1998).

Traditionally this approach has been based on the use of political support functions where the welfare of different groups have an exogenous weight. The approach was given rigorous microfoundations by Grossman and Helpman in their famous paper "Protection for Sale" (1994) in which they analyzed endogenous determination of trade policy by using a common agency framework introduced by Bernheim and Whinston

[2]In addition to giving campaign contributions, some groups may also be powerful as voters. See e.g. Lindbeck and Weibull (1987) and Dixit and Londregan (1996) who show that parties want to target redistribution to groups that have many mobile voters.

(1986). In the latter part of the 1990's the common agency framework was used to analyze various aspects of government policies. For applications to environmental policy, see Fredriksson (1997), Aidt (1998), and Schleich (1999). Fredriksson (1997) studies how pollution taxation is determined in a small open economy with a competitive polluting industry when both environmentalists and industrialists seek to influence the policy. Aidt (1998) considers a small open economy with several polluting production sectors. Part of the sectors are politically organized, and the government may use both production and input taxes and subsidies. In these papers, consumer prices of the regulated industries are determined by the world market price and the industry thus faces completely elastic demand. In that setting consumers do not face a trade-off between better environmental quality and lower price of consumption. Schleich (1999), in turn, analyzes the determination of both trade and environmental policy in a small open economy with consumption and production externalities.[3]

The first essay of my thesis extends this literature by applying the common agency framework to a new question, namely the formation of forest policies. The essay studies how the aims of wood processing industry and environmentalists are reflected in the formation of forest conservation policy, when the government conservation policy takes the form of restricting timber harvesting in areas that are particularly valuable for nontimber services of forests.

2.2 Environmental Policy in an International Setting

As mentioned above, the conflict of interests that exists between different groups of individuals in a given society may also be present at a federal or international level. Sandler (1997) provides an interesting discussion on how the conflict of interests at the international level and the political concerns within a single country influence the international development towards limiting acid rain. In particular, Sandler asks why in North America and in Europe progress has been made towards limiting sulfur emissions but not nitrogen oxide emissions. His answer has two ingredients. First, the sulfur emitters include large public utilities that are easier to control for politicians interested in re-election than, for instance, the use of private vehicles responsible for a large

[3]See also Dijkstra (2002).

fraction of nitrogen oxide emissions. Second, on average sulfur emissions travel shorter distances than nitrogen oxide emissions. This implies that the benefits of a unilateral action for an individual government are higher.

When considering the international aspect of pollution control, one important question has been whether and why non-cooperative policy design by national governments leads to inefficiencies. A related question is then what is the appropriate level of decision making, that is, should decisions on environmental policy be taken on a national or international level. As in the literature of capital or income taxation or provision of local public goods, these questions have recently received much attention as a result of the increased interdependence of national economies.

Early theoretical studies linking environmental policy and international competition focus on the effects of stringent environmental regulation on the competitiveness of domestic industries, see e.g. Pethig (1975), Siebert (1977), and McGuire (1982). These early studies have been followed by substantial literature studying how policy design may be influenced if the national governments indeed take into account the interest of domestic industries. It has been shown that under certain conditions non-cooperative policy design by national governments leads to a globally efficient outcome. This happens if polluting firms are competitive, emissions generated by production are not transboundary, and countries are small. See e.g. Oates and Schwab (1988), Rauscher (1994), Levinson (1997), and Ulph (1997).

As is often noted, however, big polluters tend to be firms operating in relatively concentrated industries, like chemical or automobile industries, where the firms are not necessarily price takers. This may have an impact on the design of environmental policies, even if the countries in question are small and emissions generated by the industry are local.[4] In a framework of strategic trade policy introduced by Brander and Spencer (1985), Barrett (1994) and Ulph (1996) show that national governments set emission standards that lead to marginal cost of abatement being lower than marginal damage caused by emissions. In a similar setting, Conrad (1993) and Kennedy (1994) show that non-cooperative emission tax rates are lower than the tax rates that would prevail if the national governments coordinated their policies so as to maximize joint

[4]See e.g. Buchanan (1969) and Barnett (1980) on the design of environmental policy in a closed economy when polluters have market power.

welfare of the countries. These results seem to support the often expressed concern that in the absence of direct trade policy measures, national environmental policies are distorted in favor of domestic producers competing in international markets. Walz and Wellisch (1997) and Tanguay (2001) in turn consider both trade and environmental policy and analyze whether, given the tendency for environmental dumping, a trade agreement that prohibits the use of trade policy increases welfare.

The analyses mentioned above concentrate on a situation where the polluting firms are national and immobile, and thus the possibility that more stringent environmental regulation would lead to production fleeing abroad is not an issue. The second essay of my thesis extends this literature by analyzing the implications of a regulatory competition between governments on environmental policies when the regulated firms are multinational. The aim is to identify how exactly the governments behave differently when the polluting firms are multinational as opposed to being national.

The second essay abstracts entirely from the location decision of the polluting firms. Typically the location of production can be expected to be influenced by several factors. Horstman and Markusen (1992) and Brainard (1997) show that horizontal multinational firms, that is, firms that have production plants in several countries, tend to exist in industries with high transportation and firm-level fixed costs and low plant-level fixed costs. Markusen and Venables (1998, 2000) study heterogenous countries and further show that horizontal multinational production occurs between countries that are similar in size as well as in relative factor endowment. For a survey of this literature, see e.g. Markusen (1995, 1998). Some recent papers study endogenous industry structures in a setting where both horizontal and vertical multinational firms may emerge. Vertical multinational production will emerge especially in situations where countries under study have very different relative factor endowments and trade costs, including tariffs and other methods of protectionism, are low. See e.g. Markusen and Maskus (2001a, 2001b).

Empirical literature on how stringent environmental regulation may affect the location of polluting industries is abundant but the evidence remains mixed. Most studies reject the so-called pollution haven hypothesis which states that polluting industries leave countries with stringent environmental regulation and move to countries with lax or non-existent environmental regulation. See e.g. Tobey (1990), Grossman and

Krueger (1993), Jaffe et al. (1995), and Levinson (1996). Some recent studies in turn suggest that this phenomenon exists, see e.g. List and Co (2000), and Antweiler et al. (2001). List and Co (2000) study the effect of heterogenous environmental regulations in the US states for plant location decisions of foreign multinational firms, and conclude that stringent environmental regulation and attractiveness of location are inversely related. Antweiler et al. (2001) study the effect of reduced trade costs on the location of polluting activities and show that the factor endowment motivation and the pollution haven motivation for the location of polluting production tend to work to opposite directions and may balance one another.

The theoretical literature analyzing policy design under a possible threat of relocation can be divided into studies that focus on the decisions of single-plant firms and into those that focus on multinational production. Motta and Thisse (1994) consider the location decision of single-plant firms in a situation where the firms are already located in one country when environmental regulation is imposed. While Motta and Thisse consider unilateral policy choices of one government, Rauscher (1995) and Hoel (1997) study the efficiency of national policy design in a situation where governments make decisions on environmental policy in a non-cooperative manner. The governments first commit to policies and the firms then decide where to locate. Greaker (2002) considers a similar situation in the framework of strategic trade policy. Ulph and Valentini (2001) in turn compare the degree of environmental dumping and welfare when 1) governments first commit to policies and firms then choose locations and 2) governments choose policies after firms have chosen locations. Dijkstra (2003) also studies policy design with and without commitment but in a setting of a single firm and quantity restrictions instead of taxation.

Multinational production may arise in Markusen et al. (1995). There, a single firm must decide whether to set up a production plant in two countries or in one country only. The trade-off for the firm is between transportation costs and plant-level fixed costs. Markusen et al. also analyze environmental policy design in two cases: 1) the firm first chooses the location of production and the governments then choose policies and 2) governments commit to policies before location choice is made. They then compare welfare and pollution levels in the two countries in these two cases. Markusen (1997) in turn considers two national firms and studies how their decision to remain national or

become multinational is affected by strict environmental regulation, but does not study policy design.

This literature reveals important insights about the behavior of governments when threatened by relocation of production and the behavior of polluting firms in the face of stricter environmental regulation. The aim of the third essay of my dissertation is to consider the role of environmental policy for multinational production from a different perspective. The starting point of the essay is the observation that there has been increasing pressure towards trade liberalization through international agreements, while environmental policy has largely remained at the discretion of national governments. I study how this change in the international regime may influence multinational production and focus on the indirect effects of this change through potential shifts in the design of national environmental policies.

3 Contents of the Dissertation

In this section I present in more detail the main research problems of the essays, discuss how the problems are analyzed, and present the main results.

3.1 Essay I: Forest Conservation - Too Much or Too Little?

In the first essay of my thesis, I analyze the design of government forest policies under interest group influence. The main question of interest is under what conditions and in what way lobbying can be expected to cause observed policies to be distorted from socially optimal policies. To analyze the incentives of different groups to use resources to influence the design of forest policy, I consider a specific policy issue, namely the conservation of forests by way of restricting harvesting. If conservation increases the cost of harvesting for the forest owner, it may also increase the cost of production for the wood processing industry. However, at the same time, it guarantees that part of the forest resources is used for other uses than timber production.

This kind of situation can be conveniently analyzed using the common agency framework, where the government is the common agent taking decisions on conservation, and different groups in the society seek to influence government decisions. I focus on a sit-

uation where the wood processing industry owns the forests subject to conservation. Thus, the main groups affected by conservation are an environmental group and an industrial group.

Wood processing industries are often highly concentrated. I therefore consider an industrial lobby that represents a non-competitive wood processing industry which is modelled as a monopoly. In this respect, the model differs from the previous common agency literature. Furthermore, in countries where the wood processing industry is important for the whole economy, changes in the price of timber may have repercussions to several sectors of the economy. I aim to capture this feature by considering a situation where imports are not a perfect substitute for domestic production of the wood processing industry. This enables me to study how the costs of conservation are distributed between producers and consumers and how the market power of the wood processing industry influences forest policy.

I study policy design in two different cases, namely when the wood product is exported and when the production of the wood processing industry is destined for domestic markets. These two scenarios are considered in order to isolate the effect of a higher consumer price on lobbying and the government forest policy. Under both scenarios, the socially optimal conservation level that maximizes the aggregate welfare is solved as a benchmark against which the effects of lobbying are evaluated.

The main findings of the essay are the following. First, comparison of the political equilibria shows that an exporting monopoly faces a stricter conservation policy than a monopoly whose production is destined for the domestic market. This is because when the wood product is exported, part of the costs of conservation are borne by foreign consumers. Second, when the industrial lobby is more efficient in lobbying than the environmental lobby, conservation policy in the political equilibrium is insufficient compared to the socially optimal conservation level. But conservation may be insufficient from the social point of view even if the environmental lobby is more efficient than the industrial lobby. This is likely to happen if the group of the politically passive consumers is large.

3.2 Essay II: Emission Tax Competition in the Presence of Multinational Firms

The design of national environmental policy in the presence of multinational firms is the topic of the second essay of my dissertation. The main questions to be addressed are: How does the emergence of multinational firms change the incentives of national governments for environmental regulation? Would coordination of environmental policies imply more lax or more severe regulation when firms are multinational?

I construct a model of two countries and two polluting firms. The two firms compete in a Cournot manner in the two markets and are said to be multinational if they have production plants in both countries. Emissions generated by the production of the firms cause local environmental problems that each government controls by levying an emission tax on the polluting firms. The governments are constrained to use only environmental policy and choose their emission tax policies non-cooperatively so as to maximize the domestic aggregate welfare, taking into account how the polluting firms react to policy changes. In order to determine the sources of the potential inefficiencies in national policy design, I also analyze a situation where the two governments coordinate their policies and choose taxation so as to maximize the joint welfare in the two countries. I start by analyzing the incentives for emission taxation when the polluting firms are national and can serve the foreign market by exports. This problem has been previously addressed in the literature, but is presented here in order to allow a clear comparison to the case of multinational firms.

The analysis confirms the previous results that emission tax competition leads to too lax environmental policy when the polluting firms are national. This happens for the reason that is often expressed in the public discussion on environmental dumping: each government has an incentive to use environmental policy to increase the market share of domestic producers and thereby profits for domestic shareholders. Relaxing emission taxation increases profits for the domestic firm but also increases the negative welfare effects of pollution. When considering a unilateral reduction in tax rate from the cooperative level, the positive effect of higher profits dominates the negative effect of increased pollution.

The main contribution of the second essay is to show that this reasoning does not

carry over to the situation where the polluting firms are multinational. Quite the contrary: When polluting firms are multinational non-cooperative emission taxation is too severe. The reason is that the incentives of national governments for environmental regulation change in two ways when firms are multinational as opposed to being national. First, when one government tightens emission taxation, both multinational firms reduce output in that country and shift production to the other country while cutting back supply in both markets. As multinational firms react in the same way to any policy change, changes in environmental policy do not influence the market share of the domestic firm. Environmental policy is thus not useful in shifting rents to the domestic shareholders. Second, when polluting firms are multinational, in each country there is a production plant that may be largely or entirely in foreign ownership. When setting policies, national governments ignore profits that accrue to foreign shareholders of these plants and are inclined to set too severe emission taxation.

3.3 Essay III: International Trade Agreements, Environmental Policy, and Emergence of Multinational Firms

One important factor influencing the degree of multinational production is government policies, obvious examples being import tariffs and investment barriers. Another example that has received a lot of attention in recent years is the potential effect of national environmental regulation. The role of environmental policy has been studied in a setting where strict environmental regulation increases the production costs of polluting firms and relocation of production may occur as the firms seek to move production to locations with lower production costs.

The third essay of my dissertation considers the role of environmental policy for multinational production from a different perspective. In the essay, I study how international trade agreements may influence multinational production. The aim of the essay is not to study the direct effects of, for instance, the reduction of trade and investment barriers, which have received a lot of attention in the literature. Instead, I consider a trade agreement that prevents the use of export subsidies for domestic producers and focus on the indirect effects of the agreement on the attractiveness of multinational production through changes in the design of national environmental policy. The main

questions of interest are the following: How does national policy design influence firms' incentives to invest in production capacity in a foreign country? How does the change in the international institutional regime affect the role of policy design?

In order to address these questions, I consider a situation of two countries and two polluting firms. Initially each firm is established in one country, has two production plants, and sells its product to a third market. The two firms may invest abroad by closing one plant in their home country and opening a new plant abroad. I analyze the incentives of the firms to do that under two different regimes. Under the first regime, national governments may use export subsidies and emission taxation. Under the second regime, a trade agreement prohibits the use of export subsidies. When using environmental policy, the national governments are constrained to set a uniform tax rate on all polluting plants within their territory.[5]

The main result of the essay is that a change in the international regime that restricts the instrument set available to the national governments may increase the attractiveness of multinational production. The reason is the following: When the governments cannot use export subsidies and the firms are national, governments use environmental policy not only to correct the negative externality caused by production but also to shift profits to the domestic shareholders. In this situation, foreign owned plants not only eliminate the possibility to use environmental policy to shift profits to the domestic shareholders but also create an incentive to tax profits accruing to foreign shareholders. In contrast, when the governments can use both environmental and trade policy, an investment abroad does not have similar strategic effects.

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Essay I

Forest Conservation - Too Much or Too Little?

A Political Economy Model

Abstract

This paper studies the formation of forest policy when the government is influenced by an environmental lobby and an industrial lobby representing a non-competitive wood processing industry. Government decides on forest conservation by way of restricting timber harvesting. Lobbying is modelled as a common agency game with differences in the efficiency of lobbying. A comparison of the political equilibria shows that an exporting forest industry faces a stricter conservation requirement than a forest industry whose production is destined for the domestic markets. If the industrial lobby is more efficient than the environmental lobby, conservation is insufficient from the social point of view. However, conservation may be insufficient even if the environmental lobby is more efficient in lobbying than the industrial lobby. This is likely to happen when the group of consumers that remain politically passive is large.

Keywords: Amenity valuation, common agency, forest policy, lobbying, market power

JEL Classification: D72, Q23

1 Introduction

Forest resources are used to produce timber, but they also provide many kinds of amenities. Timber and related wood products are private goods whereas other services provided by the forests are to a large extent public. If the forest owner is not compensated for the external benefits created by the forestry, the level of socially valuable public services of the forests may remain too low.[1]

Government forest policies aim to create a balance between these different uses of forest resources. Typically people are not affected in the same way by the government's decisions, and therefore, the trade-off between the different uses of forest resources creates political tensions. Groups that often participate in the public debate on the 'correct' objective of forest policy include environmentalists, the wood processing industry, and the forest owners.[2]

Despite the debates concerning government forest policies, the formation of forest policy has not been previously analyzed in the political economy literature. How the aims of different groups within the society are reflected in the formation of forest policy is the topic of this paper. The main question of interest is under what conditions and how the influence of special interests can be expected to cause observed policies to be distorted from socially optimal policies. In order to study this question, we consider a specific policy issue, namely conservation of forests by way of restricting timber harvesting in areas that are particularly valuable for non-timber services of forests. If conservation makes harvesting more costly for the forest owner, it may also increase the cost of timber for the wood processing industry. At the same time, conservation guarantees that part of the forest resources is used for recreational and environmental purposes. For simplicity, we consider a situation where the wood processing industry owns the forests subject to conservation. Clearly, in this situation the forest industry and environmental groups have different preferences over the government's decisions and may seek to influence policy making in order to enhance their welfare.

We will analyze the situation illustrated above using the common agency model introduced by Bernheim and Whinston (1986). In the political context this model was

[1] See e.g. Koskela and Ollikainen (1999).

[2] For a discussion on forestry conflicts see, e.g. Palo and Uusivuori (1999) and references therein.

first used by Grossman and Helpman (1994) to analyze endogenous trade policy, and it has since then become a standard model to analyze government policies under interest group influence.[3]

One of the characteristics of wood processing industries is often a concentrated market structure.[4] Furthermore, in countries where the wood processing industry is important for the whole economy, changes in the price of timber may have repercussions to several sectors of the economy. As a result, forest conservation decisions affect not only the welfare of the groups that actively participate in the debate on forest conservation, but the welfare of all consumers. Finally, an industrial lobby representing a concentrated wood processing industry and an environmental lobby typically have distinct methods of lobbying and different channels of influence.

We aim to capture the features mentioned above in the following way. First, we will consider an industrial lobby that represents a non-competitive industry, which we for simplicity model as a monopoly. Second, imports will not be a perfect substitute for domestic production of the wood processing industry. These aspects of the model imply that forest conservation influences the welfare of all consumers through changes in consumer price. They therefore enable us to study how the costs of conservation are distributed between producers and consumers and how the market power of the wood processing industry influences the political determination of forest conservation. In order to isolate the welfare-effects of forest conservation through the consumer price, we study policy design in two different situations, in a situation where the wood processing industry exports its final product and a situation where its production is destined for domestic markets. Third, we allow for asymmetry between the two lobbies in that they need not be equally efficient in lobbying. This implies that even if the lobbies were to use a same amount of total resources in order to influence policy making, one of the lobbies may be more successful in its effort than the other.

Previous applications of the common agency model to environmental policy design concentrate on environmental and trade policies in small open economies in a setting where firms are competitive and imports are a perfect substitute to domestic production.

[3]For an illuminating discussion on the research of special interest politics, see e.g. Persson and Tabellini (2000). Hillman and Ursprung (1991) and Austen-Smith (1997) survey earlier literature.

[4]See e.g. Koskela and Ollikainen (1998) and Bergman and Brännlund (1995).

Fredriksson (1997) considers a small open economy with a non-polluting and a polluting production sector. The government uses a production tax to regulate pollution, and the owners of a fixed factor used in the polluting sector and an environmental lobby seek to influence the policy choices. Aidt (1998) considers a small open economy with several production sectors some of which are represented by a lobby. All sectors use polluting raw materials in production. Aidt shows that while a benevolent social planner would use only a tax on the raw material, in the political equilibrium the government uses a tax on the raw material as well as output taxes and subsidies. Production sectors that are represented by a lobby receive an output subsidy while the unorganized production sectors pay a tax. Also in Schleich (1999) some of the several production sectors are represented by a lobby. Only one sector is polluting, but the government may use trade and production policies in all sectors in order to correct the externality and satisfy the industry lobbies. Schleich shows that in the case of production externality the government will use only production policies. The production tax for the polluting sector will be lower than the socially optimal Pigouvian tax rate, if it is organized, and higher, if it is unorganized. Moreover, the organized non-polluting sectors get a production subsidy while the unorganized sectors pay a production tax.

The rest of the paper is organized as follows. In section 2, we describe the economy and characterize the socially optimal conservation policy. In section 3, we present the political process. In section 4, we analyze the determinants of the political equilibrium and study how it compares to the social optimum. Section 5 offers some concluding comments.

2 The Economy

2.1 Production

The economy has two production sectors. The first sector is characterized by competitive firms producing a tradable numeraire good, z, with linear technology and labor, n, as the only factor of production. All consumers own one unit of labor which they supply to either of the production sectors. Consumers earn wage, w, in both sectors. We assume that the supply of labor is large enough for the numeraire good to be produced.

The other production sector consists of a monopoly that produces a wood product, y, with timber, k, and labor with constant returns to scale technology, $y = f(k, n)$. The monopoly may use timber from its own forests or import timber for production from abroad. By exporting timber the monopoly earns the world market price for round wood, $\overline{q}$, which thus constitutes the opportunity cost of using timber in production. The cost of importing round wood for production is $\overline{q} + \tau$, where τ represents transportation costs.

As our focus is on the political process, we want to model the economy in the simplest possible way. Therefore, we abstract from the intertemporal aspects of forestry and consider steady-state annual yields. In each period, the monopoly harvests this yield, or part of it, depending on the (deterministic) world market price for round wood.

Conservation reduces forest areas available for commercial harvesting, creating a binding constraint on cuttings. Conservation decisions therefore include both a decision on what the level of conservation should be and a decision on which particular areas are chosen for conservation. Here, we will concentrate on the decision of the conservation level. The level of conservation is defined to be

$$m = K - \overline{k},$$

where K is the steady-state annual yield and $\overline{k}$ is the amount of timber that may be harvested. Conservation level $m = K$ would then imply a complete preservation policy and conservation level $m = 0$ would imply a market solution.

We will analyze two different situations: a situation where the wood product is consumed domestically and a situation where it is exported.[5] The resource constraint of this economy is

$$Y = C + X - M,$$

where Y is national income, C consumption, and X and M the value of exports and imports, respectively. Imports consist of imported numeraire good, z_M, and round wood, k_M, i.e.

$$M = z_M + k_M (\overline{q} + \tau).$$

[5]In order to clearly identify the effects of forest conservation on consumer surplus, we concentrate on the situation where the domestic production is not competing with imports.

When the wood product is exported, exports consist of the wood product, y, the numeraire good, z_X, and round wood, k_X, i.e.

$$X = p(y)\, y + z_X + k_X \overline{q},$$

where $p(y)$ is the demand schedule faced by the wood processing industry abroad.

Clearly, conservation may be so extensive that importing timber is profitable for the monopoly. If timber for production were imported, changes in conservation policy would have no effect on production costs nor the consumer price. We will therefore focus on a situation where $k_M = 0$. In that case, $k_X = \overline{k} - k$, where k is the amount of timber used in own production. National income without the benefits from forest conservation can then be written as

$$Y = z + p(y)\, y + \left(\overline{k} - k\right) \overline{q},$$

and it consists of domestic production of the numeraire good and the value of the wood product and the exported round wood.

Given that the monopoly does not import round wood for production, it maximizes profits given by

$$p(y) f(k, n) + \left(\overline{k} - k\right) \overline{q} - wn \tag{1}$$

subject to the constraint that $\overline{k} \geq k$.

The total cost of timber use consists of the opportunity cost of timber and the shadow price of harvesting. This shadow price is strictly positive when all timber harvested is used for own production, that is, when $\overline{k} = k$. In that case tightening the harvesting constraint increases the cost of timber use. (See Appendix A for details.) Let $q(m)$ denote the total cost of timber use as a function of the conservation level. From the definition of the conservation level it then follows that $q'(m) > 0$.[6] Thus the marginal effect of conservation on the unit cost of production is

$$c_m(q(m), w) = c_q(q(m), w)\, q'(m) > 0.$$

[6]Partial derivatives are denoted by $\frac{\partial \Omega}{\partial x}$, by Ω_x, or, in the case of functions of a single variable, by primes.

An increase in conservation raises the cost of production as the monopoly needs to substitute labor for timber if it wishes to maintain a given level of production.

The above discussion implies that when analyzing the incentives to use resources in lobbying, of particular interest is the situation where the constraint on harvesting is such that all timber harvested is used for own production and conservation is not extensive enough to induce imports. In this situation changes in conservation policy influence the cost of production and the price of consumption.

2.2 Consumers

The economy consists of three kinds of consumers. The overall size of the population is normalized to one. Fraction α of the population owns the timber using monopoly and earns monopoly profits. In the political process consumers belonging to this group form the industrial lobby. Fraction β of the consumers belong to the environmental lobby.[7] These groups are assumed to be disjoint. Fraction $(1-\alpha-\beta)$ of the consumers belongs to neither of the above mentioned groups and remains passive in the political process.

Consumers belonging to lobby i contribute to their group's objective by providing their share of the total resources, $T_i(m)$, used by the lobby. In this setting, it is natural to think of the environmental lobby as a legitimate, national environmental organization that participates to the formation of government policies. From the point of view of an individual that belongs to the environmental organization, the contribution could be interpreted as a membership fee.[8] Net income of consumers in different groups are

[7] As only two groups participate to the political process, it is conceivable that they could reach an agreement on the appropriate level of conservation through negotiation. Since typically the most visible way of influencing conservation decisions is the direct influence on government decision making, we concentrate on that situation.

[8] It is conceivable that a monopoly lobby is able to control free riding of its members fairly efficiently. The same may not be true for large environmental organizations. See Olson (1965), Stigler (1971), and Peltzman (1976) for seminal contributions on this issue. For endogenous formation of lobby groups in the common agency setting, see Mitra (1999).

then

$$\begin{aligned} I_\alpha &= w + \frac{1}{\alpha}\pi(p, q(m), w) - \frac{1}{\alpha}T_\alpha(m), \\ I_\beta &= w - \frac{1}{\beta}T_\beta(m), \text{ and} \\ I_{1-\alpha-\beta} &= w. \end{aligned}$$

When there exists a domestic market for the wood product, the utility maximizing demands for the wood product and the numeraire good are derived as solutions to the following optimization problems:

$$\max_{z,y} \{z + u(y) + g(m)\} \text{ s.t. } I_i = z + py \text{ for } i = \alpha, \beta, 1-\alpha-\beta,$$

where $u(y)$ is utility from consumption of the wood product, $g(m)$ is utility from conservation, and p is the price of the wood product.[9] All members of the society benefit equally from conservation. This assumption highlights the idea that the most important nontimber services of forests are pure public goods, like forests as a stock for carbon or for biodiversity.[10]

Since the utility function is quasi-linear, the demand of the wood product depends only on its own price and can be expressed as $y = d(p)$. The demand of the numeraire good is then

$$z_i(p) = I_i - pd(p) \text{ for } i = \alpha, \beta, 1-\alpha-\beta,$$

where I_i is the net income of a consumer in group i. Given $d(p)$ and $z_i(p)$, the policy preferences of the consumers in different groups can be represented by the following

[9] As usual, $u' > 0$, $u'' < 0$, $g' > 0$, and $g'' < 0$. Both $u(y)$ and $g(m)$ satisfy Inada conditions.

[10] An alternative assumption would be that only consumers belonging to the environmental lobby benefit from conservation, for instance, because they value the recreational opportunities created by forests.

indirect utility functions:

$$\begin{aligned} V_{\alpha}(m) &= w + cs(m) + g(m) + \frac{1}{\alpha}\pi(p, q(m), w) - \frac{1}{\alpha}T_{\alpha}(m) \\ &= \frac{1}{\alpha}\left[\phi_{\alpha}(m) - T_{\alpha}(m)\right], \\ V_{\beta}(m) &= w + cs(m) + g(m) - \frac{1}{\beta}T_{\beta}(m) \\ &= \frac{1}{\beta}\left[\phi_{\beta}(m) - T_{\beta}(m)\right], \\ V_{1-\alpha-\beta}(m) &= w + cs(m) + g(m) \\ &= \frac{1}{1-\alpha-\beta}\phi_{1-\alpha-\beta}(m), \end{aligned} \tag{2}$$

where $cs(m) = u(d(p(m))) - p(m)\,d(p(m))$, and the gross welfare of group i is $\phi_i(m)$.

2.3 Socially Optimal Conservation Policy

We now study how conservation influences welfare of the different groups in the economy and characterize the socially optimal conservation policy. Aggregate welfare is represented by a utilitarian welfare function. We define two different welfare measures. Aggregate gross welfare consists of consumer surplus, monopoly profits, and utility from conservation. Aggregate net welfare in turn refers to aggregate welfare net of lobbying costs. When the wood product is consumed domestically, the latter is given by

$$W^{d}(m) = \phi^{d}(m) - T_{\alpha}(m) - T_{\beta}(m),$$

where

$$\begin{aligned} \phi^{d}(m) &= \phi^{d}_{\alpha}(m) + \phi^{d}_{\beta}(m) + \phi^{d}_{1-\alpha-\beta}(m) \\ &= w + cs(m) + g(m) + \pi(p, q(m), w) \end{aligned} \tag{3}$$

is the aggregate gross welfare and superscript d refers to domestic consumption.

The effects of a change in conservation on the gross welfare of different consumer groups are given by

$$\frac{\partial \phi^{d}_{\alpha}(m)}{\partial m} = \pi_{m}(p, q(m), w) + \alpha\left[cs_{m}(m) + g'(m)\right], \tag{4}$$

$$\frac{\partial \phi_{\beta}^{d}(m)}{\partial m} = \beta \left[cs_m(m) + g'(m) \right], \tag{5}$$

and

$$\frac{\partial \phi_{1-\alpha-\beta}^{d}(m)}{\partial m} = (1-\alpha-\beta) \left[cs_m(m) + g'(m) \right], \tag{6}$$

where

$$\begin{aligned} cs_m(m) &= -u'' \left(y\left(m\right) \right) y\left(m\right) y_m\left(m\right) < 0, \text{ and} \\ \pi_m\left(p, q(m), w\right) &= -y\left(m\right) c_m\left(q\left(m\right), w \right) < 0, \end{aligned}$$

and $y\left(m\right)$ denotes the profit maximizing output level as a function of the conservation level.

A stricter conservation policy reduces consumer surplus as it increases the price of consumption. It also reduces the maximum profits of the wood processing industry. However, a stricter conservation policy also directly benefits all consumers. Therefore, the optimal conservation level is strictly positive. Under the assumption that the second-order condition for welfare maximization is satisfied, the socially optimal conservation level, m^{d*}, is determined by

$$\frac{\partial \phi^{d}(m^{d*})}{\partial m} = \frac{\partial \phi_{\alpha}^{d}(m^{d*})}{\partial m} + \frac{\partial \phi_{\beta}^{d}(m^{d*})}{\partial m} + \frac{\partial \phi_{1-\alpha-\beta}^{d}(m^{d*})}{\partial m} = 0. \tag{7}$$

In the social optimum, the marginal benefit of increased conservation equals the cost imposed on consumers and monopoly owners in the form of higher consumption price and lower profits. Equation (7) implies that $\frac{\partial \phi_{\alpha}^{d}(m^{d*})}{\partial m} < 0$ and $\frac{\partial \phi_{\beta}^{d}(m^{d*})}{\partial m} > 0$.

When the final product of the wood processing industry is exported, aggregate net welfare is $W^{e}\left(m\right) = \phi^{e}(m) - T_{\alpha}(m) - T_{\beta}(m)$, where

$$\begin{aligned} \phi^{e}\left(m\right) &= \phi_{\alpha}^{e}(m) + \phi_{\beta}^{e}(m) + \phi_{1-\alpha-\beta}^{e}(m) \\ &= w + g\left(m\right) + \pi\left(p, q(m), w\right) \end{aligned} \tag{8}$$

is the aggregate gross welfare and the superscript e refers to exported wood product. In the social optimum

$$\frac{\partial \phi^{e}(m^{e*})}{\partial m} = \frac{\partial \phi_{\alpha}^{e}(m^{e*})}{\partial m} + \frac{\partial \phi_{\beta}^{e}(m^{e*})}{\partial m} + \frac{\partial \phi_{1-\alpha-\beta}^{e}(m^{e*})}{\partial m} = 0. \tag{9}$$

In both cases, in the social optimum, welfare of the members of the environmental group is increasing in m and welfare of the monopoly owners is decreasing in m. Therefore, the interests of the two groups are clearly in conflict. This conflict reflects the nature of forests as a joint production of private goods and amenity values. In analyzing lobbying, we focus on this conflict. In addition to the effects discussed above, conservation may have other effects on the economy which are not considered here. These include, for instance, the effect of conservation on the value of forest land. Furthermore, by analyzing policy design in a static environment, we leave aside potentially interesting issues concerning, for instance, the asymmetric nature of conservation decisions.

3 The Political Process

We now turn to the determination of conservation policy when environmental and industrial lobbies influence the decision of the government. The government has two distinct objectives. It takes into account the aggregate welfare of the consumers but may also be willing to distort policy in order to receive benefits from the lobbies. The government maximizes a weighted sum of aggregate welfare and contributions from the two lobbies

$$G(m; C_\alpha^j, C_\beta^j) = a\phi^j(m) + C_\alpha^j(m) + C_\beta^j(m), \tag{10}$$

where parameter a is the weight that the government attaches to aggregate welfare of the consumers, $C_i^j(m)$ denotes contributions of lobby i contingent on the policy chosen by the government, and $j = d, e$. The relative weight of aggregate welfare could be interpreted as a measure of transparency of the political system.[11]

The objective of the lobbies is to enhance the welfare of their members by influencing the level of conservation. Restricting harvesting is an instrument that allows for conserving certain forests that are particularly valuable for nontimber services. Harvesting taxes, for instance, also typically influence the quantity harvested, but they cannot be targeted to preserve a given area. In addition, using a tax as an instrument to regulate harvesting would change the nature of the political process. Taxation would generate

[11] See e.g. Grossman and Helpman (1994) and Goldberg and Maggi (1999) for discussion.

revenue to be distributed back to the consumers and the existence of this tax revenue would create an additional motive for lobbying. As a result, lobbying would lead to pure redistribution from the unorganized groups to the organized groups. In fact, many of the distortions created by lobbying in the previous literature on environmental regulation with competitive industries stem from this additional motive.[12]

The contributions of the two lobbies represent the monetary equivalent of all the resources used to influence the political process. When considering the influence of two very different kind of lobbies, it is natural to allow for differences in the efficiency of lobbying. We follow Laffont and Tirole (1993, Ch. 11) in assuming that using resources in order to influence the government is costly in the sense that a contribution of one dollar costs $(1 + \lambda_i)$ dollars for lobby i. Therefore, total resources used by lobby i are

$$T_i(m) = (1 + \lambda_i) C_i(m).$$

Parameter λ_i is non-negative and reflects the efficiency of lobbying. When $\lambda_\alpha = \lambda_\beta$, lobbies are equally efficient. In general, λ_i depends on how the attractiveness of lobbying is influenced, for instance, by the tax code and direct regulations. In addition, λ_i is likely to be high for groups with high fund raising costs or high administrative costs, which may arise because of large and dispersed membership or because of the need to spend resources to prevent free riding. Differences in the cost of lobbying could also arise because the preferences of the government are more in line with one lobby than the other.[13]

Timing of the political game is as follows. Lobbies first choose simultaneously their contribution schedules which determine their contribution for all possible policy decisions of the government. The government then chooses the conservation level that maximizes its payoff.

[12] For instance, in Fredriksson (1997) environmental policy under lobbying would coincide with the socially optimal policy, if the tax revenue was returned to the polluting industry instead of being distributed to all consumers.

[13] A more complete analysis would then incorporate elections where the identity of the government is determined, see e.g. Grossman and Helpman (1996). Here, as is typical in the literature, the transaction cost is exogenous. Genuine incorporation of the features influencing efficiency would call for endogenization of this cost, see e.g. Faure-Grimaud et al. (1999).

Lemma 2 in Bernheim and Whinston (1986) shows that there exists a set of subgame perfect equilibria in this game. It can be readily extended to the case where lobbying is costly.

Lemma 1 *When there are strictly positive lobbying costs, policy m^j and contribution schedules $C_\alpha^j(m)$ and $C_\beta^j(m)$ form a subgame perfect equilibrium if and only if*

1) $C_i^j(m) \geq 0$ *for* $i = \alpha, \beta$
2) $m^j \in \arg\max \left\{ G(m; C_\alpha^j, C_\beta^j) \right\}$,
3) $m^j \in \arg\max \left\{ G(m; C_\alpha^j, C_\beta^j) + \frac{1}{1+\lambda_i} \left[\phi_i(m) - (1+\lambda_i) C_i^j(m) \right] \right\}$ *for* $i = \alpha, \beta$, *and*
4) $\exists\ m^{-i} \in \arg\max \left\{ G(m; C_\alpha^j, C_\beta^j) \right\}$ *with* $C_i^j(m^{-i}) = 0$.

Condition 1 states the assumption that lobbies cannot demand contributions from the government. Condition 2 states that the government chooses a policy that maximizes its payoff given the contribution schedules of the lobbies. Condition 3 states that in equilibrium, the government chooses a policy that maximizes the weighted joint payoff of the government and lobby i, the weight of the lobby depending on its efficiency. A violation of this condition at $\widetilde{m}$ would imply that lobby i could induce government to choose $\widetilde{m}$ instead of m^j by changing its contribution schedule in such a way that both lobby i and the government were strictly better off. Finally, condition 4 states that there must exist policy m^{-i} that gives the government the same payoff as the equilibrium policy and induces a zero contribution from lobby i. If not, lobby i could reduce its equilibrium contribution without inducing the government to deviate from the equilibrium policy.

As is customary in the political applications of the common agency framework, we assume that the contribution schedules of the lobbies are truthful. This means that the change in the contribution induced by a given policy change always correctly reflects the policy preferences of the lobbies. Conditions of Lemma 1 imply that the equilibrium policy is implicitly defined by

$$\frac{\partial \phi_i^j(m^j)}{\partial m} = (1+\lambda_i) \frac{\partial C_i^j(m^j)}{\partial m} \text{ for } i = \alpha, \beta, \tag{11}$$

where $j = d, e$. Hence, in the equilibrium, the marginal change in total lobbying costs of lobby i induced by a small change in conservation policy equals the marginal change

in the welfare of lobby i. The cost of lobbying essentially dampens the effect of a given policy change on the contribution of lobby i. Thus, when the lobbying cost increases, the equilibrium contribution of the lobby becomes less responsive to changes in welfare.

Plugging equation (11) into the first-order condition of the government derived from condition 2 of Lemma 1 gives

$$\left[\frac{1}{(1+\lambda_\alpha)}+a\right]\frac{\partial\phi_\alpha^j(m^j)}{\partial m}+\left[\frac{1}{(1+\lambda_\beta)}+a\right]\frac{\partial\phi_\beta^j(m^j)}{\partial m}+a\frac{\partial\phi_{1-\alpha-\beta}^j(m^j)}{\partial m}=0. \qquad (12)$$

Thus, the policy that maximizes the payoff of the government according to condition 2 of Lemma 1 also maximizes

$$\Omega^j(m)=\left[\frac{1}{(1+\lambda_\alpha)}+a\right]\phi_\alpha^j(m)+\left[\frac{1}{(1+\lambda_\beta)}+a\right]\phi_\beta^j(m)+a\phi_{1-\alpha-\beta}^j(m). \qquad (13)$$

The above discussion implies that the outcome of lobbying is efficient in the sense that it maximizes the weighed sum of the payoff of the government and the two active lobbies.[14] However, to the extent that not all consumers who are influenced by conservation decisions engage in lobbying activities, the politically determined conservation level will be inefficient from the point of view of the society as a whole.

4 Conservation as a Result of the Political Process

In this section, we analyze the relationship of the political equilibrium and the socially optimal conservation level and determine factors that influence the equilibrium outcome. We first analyze the relationship of the political equilibria when the wood product is exported and when it is consumed domestically. In addition, we study how the market power of the wood processing industry influences the political equilibria.

A comparison of the two political equilibria determined by (12) shows that

Proposition 1 *When the final product of the wood processing industry is exported, the politically determined conservation policy is stricter than when the wood product is destined for domestic consumption.*

[14] For equations (12) to characterize maxima, second-order conditions must hold. Throughout the analysis of the following section, we will assume that the second-order conditions are satisfied.

Proof. By using equations (4)-(7) it follows that for $j = d$

$$\Omega_m^d(m) = \left[\frac{1}{1+\lambda_\alpha} + a\right] \pi_m(p, q(m), w) + \varphi\left[cs_m(m) + g'(m)\right]$$

where $\varphi = \left[a + \frac{\alpha}{(1+\lambda_\alpha)} + \frac{\beta}{(1+\lambda_\beta)}\right]$. For $j = e$, equation (12) can be rewritten as

$$\left[\frac{1}{1+\lambda_\alpha} + a\right] \pi_m(p, q(m^e), w) + \varphi g'(m^e) = 0.$$

Evaluating $\Omega_m^d(m)$ at $m = m^e$ then yields $\Omega_m^d(m^e) = \varphi cs_m(m^e) < 0$. ■

This result is driven by the effects of conservation on the consumer surplus. As the wood processing industry is non-competitive, the optimal output is generally lower than the output that would prevail in a competitive market. A strict conservation policy further reduces the supply of the wood processing industry. This reduces consumer surplus and affects all the consumers when the wood product is consumed domestically.[15] However, when the wood product is exported, the negative effects of conservation are restricted to the owners of the wood processing industry. The costs of forest conservation are therefore partly borne by foreign consumers.

In order to study the effect of the market power on the politically determined forest conservation policy, for tractability, we concentrate on a situation where the demand elasticity is constant. This allows us to use the degree of the demand elasticity as a measure of the market power of the monopoly. Let $y_\varepsilon(m)$ denote the marginal influence of a change in the demand elasticity on the profit maximizing output. We then have that

Lemma 2 *When $y_\varepsilon(m) > 0$ and the wood product is exported, the equilibrium conservation level is increasing in the market power of the exporting monopoly. If the wood product is destined for the domestic market, the effect of market power on the equilibrium policy is ambiguous.*

Proof. See Appendix B. ■

[15] See e.g. Barnett (1980) on the regulation of a polluting monopoly.

If the optimal output level is increasing in the demand elasticity, the negative effect of conservation on profit is aggravated by loss of market power. When the wood product is exported, the monopoly profit is the only channel through which market power influences the effect of conservation decisions on aggregate welfare. Consequently, if the monopoly loses market power, overall social costs of forest conservation increase while the benefits remain unchanged. Hence, the conservation level is lower when the domestic wood processing industry loses market power in the export market.

When the product of the wood processing industry is destined for domestic markets, a change in the demand conditions affects the equilibrium policy through two channels. In addition to the effect on profits, changes in the market power of the industry influence the effect of conservation on the consumer surplus. However, this effect remains ambiguous. Therefore, when the wood product is consumed domestically the influence of changes in market power on the political equilibrium is ambiguous.

Consider then how the politically determined conservation policy may be distorted from the social optimum. Here, lobbying may lead the conservation policy to be inefficient for three reasons: because the wood processing industry has market power, because the two lobbies are not equally efficient in lobbying, and because not all who benefit from forest conservation take part in lobbying.[16] The results are summarized in the following proposition:

Proposition 2 *When the wood product is exported or consumed domestically*
i) if the industrial lobby is more efficient than the environmental lobby, the politically determined conservation level is insufficient from the social point of view.
ii) if the environmental lobby is more efficient than the industrial lobby, depending on how large the group of politically passive consumers is relative to the group of environmentalists, conservation may be insufficient or excessive. Conservation is more likely to be insufficient when the group of politically passive consumers is large.

[16] A fourth possible source inefficiency would be the existence of tax revenue as it creates an additional incentive for lobbying.

Proof. Solving (7) and (9) for $\frac{\partial \phi_{\alpha}^{j}(m)}{\partial m}$ and plugging into (12) gives

$$\left(\frac{1}{1+\lambda_{\alpha}}+a\right)\frac{\partial \phi^{j}(m^{j})}{\partial m}+\frac{1}{1+\lambda_{\alpha}}\left[\left(1-\frac{1+\lambda_{\alpha}}{1+\lambda_{\beta}}\right)\frac{\partial \phi_{\beta}^{j}(m^{j})}{\partial m}+\frac{\partial \phi_{1-\alpha-\beta}^{j}(m^{j})}{\partial m}\right]=0.$$

Hence, for $j=d$,

$$\begin{aligned}\frac{\partial \phi^{d}(m^{d})}{\partial m} &= \frac{1}{(1+a(1+\lambda_{\alpha}))}\left[\frac{\lambda_{\beta}-\lambda_{\alpha}}{(1+\lambda_{\beta})}\frac{\partial \phi_{\beta}^{d}(m^{d})}{\partial m}+\frac{\partial \phi_{1-\alpha-\beta}^{d}(m^{d})}{\partial m}\right] \\ &= \frac{\left[(1-\alpha-\beta)(1+\lambda_{\beta})+\beta(\lambda_{\beta}-\lambda_{\alpha})\right]\left[g'\left(m^{d}\right)+cs_{m}\left(m^{d}\right)\right]}{(1+\lambda_{\beta})(1+a(1+\lambda_{\alpha}))}.\end{aligned}$$

In the same manner, for $j=e$,

$$\frac{\partial \phi^{e}(m^{e})}{\partial m}=\frac{\left[(1-\alpha-\beta)(1+\lambda_{\beta})+\beta(\lambda_{\beta}-\lambda_{\alpha})\right]g'(m^{e})}{1+(1+\lambda_{\alpha})a}$$

Since $g'\left(m^{d}\right)+cs_{m}\left(m^{d}\right)>0$ and $g'(m)>0$, a sufficient condition for $\frac{\partial \phi^{d}\left(m^{d}\right)}{\partial m}>0$ and $\frac{\partial \phi^{e}(m^{e})}{\partial m}>0$ is $\lambda_{\alpha}<\lambda_{\beta}$. A necessary condition for $\frac{\partial \phi^{d}\left(m^{d}\right)}{\partial m}<0$ and $\frac{\partial \phi^{e}(m^{e})}{\partial m}<0$ in turn is that $\lambda_{\alpha}-\lambda_{\beta}>\frac{1-\alpha-\beta}{\beta}(1+\lambda_{\beta})$. ■

When the wood product is exported, the only group that is adversely affected by an increase in the conservation level is the monopoly owners. All the other consumers benefit from stricter conservation policies. When the wood product is consumed domestically, all consumers are influenced by the conservation decisions also through the consumer price. In both cases, if the industrial lobby is at least as efficient as the environmental lobby, the politically determined conservation level is insufficient relative to the socially optimal conservation level.

However, the conservation level may remain too low even if the environmental lobby is more efficient than the industrial lobby. This happens especially if the group of politically passive consumers is large. The reason is that the passive consumers benefit from the lobbying effort of the environmental lobby, but the objective of the group is to maximize the welfare of its members only. This means that the environmental lobby does not take into account the benefits of its lobbying effort for the other groups in the society. The politically determined conservation will be excessive only if the

environmental lobby is sufficiently more efficient than the industrial lobby. This is likely to be the case if the difference in lobbying efficiencies is substantial relative to the ratio of the population share of the politically passive consumers and the politically active environmentalists.

As mentioned earlier, it is conceivable that the industrial lobby is able to control free riding better than a large environmental group with a disperse membership. Of course, making lobbying prohibitively expensive for both lobbies would guarantee that policy design reflects the social optimum. However, without precise knowledge of what are the most important factors influencing the efficiency of lobbying, this policy could lead to substantial inefficiencies. This is an area for future research.

5 Conclusions

This paper has used a political economy approach to analyze the design of forest policy. More specifically, we have studied how forest conservation policy is determined when the government is influenced by an industrial and an environmental lobby. Policy formation has been modelled as a common agency game.

Decisions of the government affect the welfare of consumers in several ways. First, forest conservation increases the harvesting cost and thereby the cost of production. Consequently, conservation decisions affect the maximum profits of the wood processing industry. In addition, if the wood product is destined for domestic consumption, increased conservation requirement affects the welfare of all the domestic consumers through a higher price of consumption. Finally, conservation benefits all consumers by guaranteeing a certain level of non-timber services.

Comparison of the political equilibria shows that an exporting monopoly faces a stricter conservation policy than a monopoly whose production is destined for the domestic market. When the wood product is exported, part of the costs of conservation are borne by foreign consumers. The more elastic the demand of the wood product abroad, the more severely the industry is affected by an increased conservation requirement. Hence, a change in the international environment that causes the domestic industry to face more elastic demand abroad limits the willingness of the government to engage in forest conservation.

When the wood product is exported, conservation decisions influence the profits of the wood processing industry but affect all consumers only through the benefit derived from nontimber services of forests. Hence, the environmentalists and the politically passive consumers always benefit from stricter conservation policies. When the wood product is destined for the domestic market, all consumers are affected by conservation also through the higher consumer price. In both cases, when the industrial lobby is more efficient than the environmental lobby, conservation policy in the political equilibrium is insufficient compared to the socially optimal conservation level. But conservation may be insufficient from the social point of view even if the environmental lobby is more efficient than the industrial lobby. This is likely to happen if the group of the politically passive consumers is large.

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A Appendix

Lagrangian of the constrained optimization problem of the monopolist is

$$L\left(k,n,\lambda\right)=p\left(f\left(k,n\right)\right)f\left(k,n\right)+\left(\overline{k}-k\right)\overline{q}-wn+\lambda\left(\overline{k}-k\right).$$

Using $\varepsilon=-\frac{df(k,n)}{dp(\cdot)}\frac{p(\cdot)}{f(k,n)}$ the associated first-order conditions are

$$L_k\left(k,n,\lambda\right)=0\Leftrightarrow\left(1-\frac{1}{\varepsilon}\right)pf_k\left(k,n\right)=\overline{q}+\lambda, \tag{A1}$$

$$L_n\left(k,n,\lambda\right)=0\Leftrightarrow\left(1-\frac{1}{\varepsilon}\right)pf_n\left(k,n\right)=w, \text{ and} \tag{A2}$$

$$L_\lambda\left(k,n,\lambda\right)=0\Leftrightarrow\overline{k}-k=0. \tag{A3}$$

Define $q=\overline{q}+\lambda$. The first-order conditions establish a maximum, since the bordered Hessian matrix

$$H=\begin{bmatrix}0 & -1 & 0\\ -1 & \pi_{kk} & \pi_{kn}\\ 0 & \pi_{nk} & \pi_{nn}\end{bmatrix}$$

is negative semi-definite. Totally differentiating (A1)-(A3) with respect to λ and $\overline{k}$ yields

$$\begin{bmatrix} \frac{\partial^2 L}{\partial \lambda^2} & \frac{\partial^2 L}{\partial \lambda \partial k} & \frac{\partial^2 L}{\partial \lambda \partial n} \\ \frac{\partial^2 L}{\partial k \partial \lambda} & \frac{\partial^2 L}{\partial k^2} & \frac{\partial^2 L}{\partial k \partial n} \\ \frac{\partial^2 L}{\partial n \partial \lambda} & \frac{\partial^2 L}{\partial k \partial n} & \frac{\partial^2 L}{\partial n^2} \end{bmatrix} \begin{bmatrix} \frac{d\lambda}{d\overline{k}} \\ \frac{dk}{d\overline{k}} \\ \frac{dn}{d\overline{k}} \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \\ 0 \end{bmatrix}.$$

Thus when $\overline{k} = k$,

$$\frac{dq}{d\overline{k}} = \frac{d\lambda}{d\overline{k}} = \frac{-\left[\pi_{kk}\pi_{nn} - \pi_{kn}\pi_{nk}\right]}{|H|} < 0 \text{ and } \frac{d^2 q}{d\overline{k}^2} = 0.$$

B Appendix

Proof of Lemma 2. When $\overline{k} - k = 0$, the profit function of the monopoly is

$$\pi\left(p, q(m), w\right) = \max_{y} \left\{p\left(y\right) y - c(q(m), w)y\right\}, \tag{B1}$$

and hence the optimal output level is determined by

$$p\left(y\right) + p'\left(y\right) y - c(q(m), w) = 0. \tag{B2}$$

Using $p = y^{-\frac{1}{\varepsilon}}$ where $\varepsilon = -\frac{dy}{dp}\frac{p}{y}$ gives $y\left(m\right) = \left[\frac{c(q(m),w)}{1-\frac{1}{\varepsilon}}\right]^{-\varepsilon}$ and

$$y_m\left(m\right) = -\varepsilon y\left(m\right) \frac{c_m(q(m), w)}{c(q(m), w)} < 0. \tag{B3}$$

If ε is constant

$$\begin{aligned} y_\varepsilon\left(m\right) &= y\left(m\right)\left[-\ln\left[\frac{c(q(m), w)}{1-\frac{1}{\varepsilon}}\right] + \frac{1}{\varepsilon - 1}\right] \\ &= y\left(m\right)\left[-\ln\left[y\left(m\right)^{-\frac{1}{\varepsilon}}\right] + \frac{1}{\varepsilon - 1}\right]. \end{aligned}$$

When $y\left(m\right) > 1$ the optimal output is increasing in the demand elasticity. Totally differentiating first-order condition (12) yields

$$\frac{dm^j}{d\varepsilon} = -\frac{\Omega^j_{m\varepsilon}\left(m^j\right)}{\Omega^j_{mm}\left(m^j\right)},$$

where $\Omega^j_{mm}(m^j) < 0$. For $j = e$

$$\Omega^e_{m\varepsilon}(m^e) = -\left(\frac{1}{1+\lambda_\alpha} + a\right) y_\varepsilon(m)\, c_m\left(q\left(m^e\right), w\right).$$

If $y_\varepsilon(m) > 0$ it directly follows that $\Omega^e_{m\varepsilon}(m^e) < 0$. As a result, $\frac{dm^e}{d\varepsilon} < 0$. For $j = d$

$$\Omega^d_{m\varepsilon}(m^d) = \left(a + \frac{1}{1+\lambda_\alpha}\right)\pi_{m\varepsilon}\left(p, q\left(m^d\right), w\right) + \left(a + \frac{\alpha}{1+\lambda_\alpha} + \frac{\beta}{1+\lambda_\beta}\right) cs_{m\varepsilon}\left(m^d\right).$$

Using $p = y^{-\frac{1}{\varepsilon}}$ gives that

$$cs_m(m) = -\frac{\varepsilon c_m\left(q(m), w\right)}{\varepsilon - 1} y(m)$$

and hence

$$cs_{m\varepsilon}(m) = \frac{c_m\left(q(m), w\right)}{(\varepsilon-1)^2} y(m) - \frac{\varepsilon c_m\left(q(m), w\right)}{\varepsilon - 1} y_\varepsilon(m).$$

When $y_\varepsilon(m) > 0$, the effect of market power on consumer surplus remains ambiguous.

■

Essay II

Environmental Tax Competition in the Presence of Multinational Firms

Abstract

We study the design of environmental policy in a two country model with an imperfectly competitive polluting industry. We show that while non-cooperative policy design leads to too lax emission taxation when polluting firms are national, it leads to too severe taxation when they are multinational. The reason is twofold. When firms are multinational, environmental policy is not useful in shifting rents to domestic shareholders. In addition, when designing their policies, national governments ignore profits accruing to foreign shareholders of multinational firms.
Keywords: Environmental policy, multinational firms, tax competition
JEL Classification: D62, F23, H77

1 Introduction

Multinational firms play an increasingly important role in international competition. In 1997, the gross product of all multinational firms accounted for roughly one quarter of the world's gross product. In addition, global sales of foreign affiliates of multinational firms were twice as high as global exports indicating that to a large extent multinational firms spread horizontally, that is, exports are at least partially replaced by foreign production.[1]

An often expressed concern is that the increasing dominance of multinational firms will undermine the efficiency of national environmental regulation. When faced with tightening environmental regulation, multinational firms, unlike national firms, are able to shift production from one country to another so as to escape higher tax rates. The fear is that this may induce national governments to relax environmental protection in order to prevent domestic production from fleeing abroad. Despite this concern, the problem of regulating multinational polluting firms has received little attention in the economics literature.

In contrast, the possible inefficiency of national environmental policies when polluting firms are national has been studied by several authors. This literature provides a starting point and background for the present study. It is well established that when the international market is perfectly competitive and environmental damage caused by emissions is local, there is no reason to expect environmental policy of a small country to be distorted.[2] However, when polluting firms have market power matters may be different.

In a framework of strategic trade policy introduced by Brander and Spencer (1985),[3] Barrett (1994) and Ulph (1996) show that national governments set emission standards that lead to marginal cost of abatement being lower than marginal damage caused by emissions. In a similar setting, Conrad (1993) and Kennedy (1994) show that non-cooperative emission tax rates are lower than the tax rate that would prevail if the national governments coordinated their policies so as to maximize joint welfare of the

[1] See UNCTAD (2000) and Markusen (1998).

[2] See e.g. Oates and Schwab (1988), Rauscher (1994), and Ulph (1997).

[3] See Brander (1995) for a survey of this literature.

countries. Intuition for these results is the following. Relaxing environmental standards induces domestic producers to expand output and their foreign rivals to reduce output. Increased market share yields higher profits for domestic shareholders and this positive effect dominates the negative welfare-effect caused by increased emissions.[4] All these papers study policy design in the presence of single plant, immobile firms.

Several authors have also analyzed the implications of plant mobility on the non-cooperative environmental policy design. Ulph and Valentini (2001) compare the non-cooperative environmental policies when polluting firms first decide where to locate and governments then choose policies and when the governments first commit to policies and the firms then choose their location. They study the issue in the strategic trade policy framework with two single-plant firms and show that environmental policy may be stricter in the case where the governments first commit to policies, that is, when the firms are completely foot-loose. Rauscher (1995) and Hoel (1997) in turn consider the efficiency of non-cooperative environmental policies in a setting where the governments first commit to a policy and the single-plant firms then locate to the country with the most favorable policy. In this setting, non-cooperative policies may be either too strict or too lax. Dijkstra (2003) also studies policy design with and without commitment but in a setting of a single firm and quantity restrictions instead of taxation. He compares regional and national policy design and shows that regional policy design may be better when the governments cannot commit.

In Markusen et al. (1995) multinational production may arise. A single firm must decide whether to set up a production plant in two countries or in one country only. The trade-off for the firm is between transportation costs and plant-level fixed costs. Markusen et al. analyze environmental policy design in two cases: 1) the firm first chooses the location of production and the governments then choose policies and 2) policies are chosen before location of production. They then compare welfare and pollution levels in the two countries in these two cases. Markusen (1997) in turn considers two national firms and studies how their decision to remain national or become

[4] As noted by several authors, these results may change if producers compete in prices instead of quantities (see e.g. Eaton and Grossman, 1986, Barrett, 1994, and Conrad, 1996), if there are general equilibrium effects in factor markets (see e.g. Dixit and Grossman, 1986, and Rauscher, 1994) or if the domestic production sector consists of several firms (Barrett, 1994, and Nannerup, 2001).

multinational is affected by strict environmental regulation, but does not study policy design.

This paper focuses on the design of national environmental policy in the presence of multinational firms producing in two countries. In general, there may be several reasons to become multinational.[5] We do not study the decision to become multinational, but assume instead that the industry already exists when environmental regulation is imposed on the firms. The main questions to be addressed are: How does emergence of multinational firms change the incentives of national governments for environmental regulation? What are the sources of potential inefficiencies in national policy design? When the polluting firms are multinational, would coordination of environmental policies imply more lax or more severe regulation?

Following the literature on strategic trade and environmental policy, we build a two country model of regulatory competition and extend it to multinational firms. Each national government controls the level of emissions by levying a tax on emissions generated in its country. The governments are constrained to set a uniform tax rate that applies to all polluting plants within their territory.[6] Policy design is analyzed under two different industry structures. In the first case, the two countries are occupied by national firms that serve the foreign market by exports. In the second case, the countries are occupied by multinational firms. By multinational firms we mean firms that have production plants in more than one country and are therefore able to shift production from one country to another as a reaction to government policies. This reflects the assumption stated above that being multinational is advantageous in the sense that it allows the firm to respond more efficiently to changes in national regulatory environment.[7]

[5] For a survey of the literature on multinational production, see Markusen (1998, 1995). We discuss the rationale for multinational production in more detail in the third essay of this dissertation and analyze the decision to become multinational.

[6] This would be the case for instance within the EU single market.

[7] The framework in Hoel (1997) resembles our approach although does not include multinational production. In Hoel, the governments first choose policies and each firm then decides where to locate. In the policy stage, there are multiple equilibria. Firms make zero profit and, consequently, the allocation of firms and production is arbitrary. If the two governments have chosen same policies, production takes place in both countries assuming that half of the firms locate in each country. Here,

We confirm the previous finding that setting emission taxation in a non-cooperative manner leads to too lax emission regulation when the polluting firms are national. However, when the polluting firms are multinational, competition between the governments leads to too severe emission taxation. Thus, relaxing emission taxation from the non-cooperative level increases welfare in both countries. The reason is that the incentives of national governments for environmental regulation change in two ways when firms are multinational as opposed to being national. First, multinational firms react in the same way to any policy change. Hence, changes in environmental policy do not influence the market share of the domestic firm and, consequently, environmental policy is not useful in shifting rents to domestic shareholders. Second, when polluting firms are multinational, in each country there is a production plant that is entirely in foreign ownership. When setting policies, national governments ignore profits that accrue to foreign shareholders of these plants and are inclined to set too severe emission taxation.[8]

The remaining of the paper is organized as follows. In section 2 we present the set-up. In sections 3 and 4 we analyze emission tax policies in the case of national firms and multinational firms. Section 5 concludes.

2 The Set-Up

We consider a model of two identical countries, home and foreign, and a polluting industry consisting of one firm in each country. Consumers in the two countries benefit from consumption of the good produced by the firms, but experience a welfare loss due to harmful emissions generated by production. Both firms may supply both foreign and

in the case of multinational firms, firms are established in two countries when the governments choose policies. After that the firms decide where to produce which then unambiguosly determines overall output in the two countries.

[8]This motive for taxation is also present in previous work on corporate taxation, for instance in Huizinga and Nielsen (1997) in a context of a small open economy and in Janeba (1996) in a framework of strategic trade policy. In Janeba the two firms are single-plant firms and produce in the same country, but one of them operates through a subsidiary.

home market. The aggregate supply in home market, X, is

$$X = x^H + x^F,$$

where x^H is supply by home firm and x^F supply by foreign firm. In the same manner, aggregate supply in foreign market, X^*, is

$$X^* = x^{*H} + x^{*F},$$

where x^{*H} is supply by home firm and x^{*F} is supply by foreign firm. The revenue of firm $j = H, F$ is then

$$p(X)\, x^j + p(X^*)\, x^{*j},$$

where $p(\cdot)$ is the inverse demand function in the two countries. We will assume that

Assumption 1 *Demand function satisfies:*[9]

$$p'(\cdot) < 0 \textit{and } p''(\cdot)\, h + p'(\cdot) < 0 \textit{ for } h = x^H, x^F, x^{*H}, x^{*F}.$$

The plant level production cost function for each firm is $c(\cdot)$. The two firms possess technology to abate emissions generated by production and the plant level abatement cost function for both firms is $g(\cdot)$. Throughout the paper we assume that

Assumption 2 *Production and abatement cost functions satisfy:*

$$c'(\cdot) > 0,\ g'(\cdot) > 0, \textit{ and } c''(\cdot) > 0,\ g''(\cdot) > 0.$$

Assumption 1 implies decreasing marginal revenue. Convex production costs in turn reflect the idea that expanding production in one plant becomes increasingly costly as the level of production increases. Constant marginal costs would imply that production in one plant could be increased without limit and even a marginal change in emission

[9] Derivates of functions of one argument are denoted by primes. Subscripts refer to partial derivatives of functions of several arguments.

tax rate would induce multinational firms to shift all production from one country to another.[10] Together Assumptions 1 and 2 are sufficient to guarantee that the second-order conditions for profit maximization for national and multinational firms are satisfied and that the reaction functions of the firms are downward sloping.

Let y^j denote the plant level production of firm j. We choose units of emission so that when the plant level abatement of firm j is a^j, emissions generated by the production of that plant, e^j, are

$$e^j = y^j - a^j.$$

National governments control the level of emissions by levying an emission tax. Each government levies a tax on emissions generated in its own country.[11] Tax revenue is distributed back to consumers as lump sum transfers. Let $\mathbf{t} = (t, t^*)$ denote the vector of emission tax rates where t is the tax rate in home country and t^* in foreign country. Emissions generated by production are local, and the overall level of emissions in home country is E and in foreign country E^*. The negative welfare-effect of emissions is $d(E)$ in home country and $d(E^*)$ in foreign country with $d'(\cdot) > 0$ and $d''(\cdot) \geq 0$.

Using the framework presented above, we will analyze the design of environmental policy under two different industry structures. In the first case to be analyzed, firms are national and may serve foreign market by exports. Total costs of production for home firm are then

$$c\left(y^H\right) + g\left(a^H\right) + te^H$$

and for foreign firm

$$c\left(y^F\right) + g\left(a^F\right) + t^*e^F.$$

As both firms have only one production plant, $E = e^H$ and $E^* = e^F$.

[10] Plant level fixed set-up costs are not explicitly considered here as the number of plants is exogenous. We assume that these costs are such that only two firms exist in the market despite the convex production costs.

[11] An alternative approach would be to consider quantity restrictions. In the setting of strategic environmental policy, these two instruments need not be exactly equivalent. See Ulph (1996) and references therein.

In the second case, the two countries are occupied by two multinational firms, both having one production plant in each country. In order to distinguish between the two plants of one firm located in different countries, we let a star refer to a production plant located in foreign country. Total costs of production for firm j are then

$$c\left(y^j\right) + c\left(y^{*j}\right) + g\left(a^j\right) + g\left(a^{*j}\right) + te^j + t^*e^{*j}.$$

Consequently, when firms are multinational, $E = e^H + e^F$ and $E^* = e^{*H} + e^{*F}$. Throughout the paper we consider a simple ownership structure where home firm is owned by residents of home country and foreign firm by residents of foreign firm.[12]

Timing of the events is as follows. The national governments of the two countries first simultaneously set their emission tax rates. After the policies have been chosen, the firms decide how much to produce and how much to supply in each market. The multinational firms also decide where to produce. We solve the problem in the usual manner by backward induction.

3 Tax Policy and National Firms

This section provides a background and starting point for the next section, where environmental policy in the presence of multinational firms is analyzed. The results of this section are qualitatively same as in the previous literature. That is, when polluting firms are national and compete in Cournot manner, national environmental policies are too lax.[13]

We begin by solving the profit maximization problems of the national firms given the tax policies chosen by the two governments. After that we consider first non-cooperative policy design and then policy design under coordination. Countries being identical, we focus mainly on home firm and home government.

[12] On the effect of cross-ownership on government policies, see Van Long and Soubeyran (2001) and Huizinga and Nielsen (1997). On endogenous ownership structure, see Olsen and Osmundsen (2001) and references therein.

[13] Our model most closely resembles that in Kennedy (1994).

3.1 National Firms

Let π^H denote profits of home firm. Given any pair of tax rates (t, t^*) set by the national governments, the profit maximization problem of home firm is

$$\max_{y^H, a^H, x^{*H}} \pi^H = p(X)\, x^H + p(X^*)\, x^{*H} - c\left(y^H\right) - g\left(a^H\right) - te^H$$

where X and X^* are aggregate supplies in home and foreign market and $x^H = y^H - x^{*H}$. The first-order conditions for profit maximization for home firm are

$$\frac{\partial \pi^H}{\partial y^H} = p'(X)\, x^H + p(X) - c'\left(y^H\right) - t = 0, \tag{1}$$

$$\frac{\partial \pi^H}{\partial a^H} = t - g'\left(a^H\right) = 0, \tag{2}$$

$$\frac{\partial \pi^H}{\partial x^{*H}} = p'(X^*)\, x^{*H} + p(X^*) - p'(X)\, x^H - p(X) = 0. \tag{3}$$

The first-order conditions of foreign firm are derived in an analogous manner. The conditions imply that decisions on output, abatement, and supply are optimal when marginal production cost equals marginal revenue, marginal abatement cost equals emission tax rate, and marginal revenues in the two markets are equalized. We denote the profit maximizing output, supplies, and emission level of firm j as a function of the tax rates by $y^j(\mathbf{t})$, $x^j(\mathbf{t})$, $x^{*j}(\mathbf{t})$, and $e^j(\mathbf{t})$. As demand conditions are identical in the two countries, the firms divide their output equally between the two markets, i.e. $x^{*j}(\mathbf{t}) = x^j(\mathbf{t})$ for $j = H, F$. Consequently, $X^*(\mathbf{t}) = X(\mathbf{t})$.

Given Assumptions 1 and 2, from the first-order conditions it follows that

Lemma 1 *When home government tightens emission control, home firm cuts down supply in both markets and foreign firm expands supply in both markets. Emissions decrease in home country and increase in foreign country. Aggregate supply in both markets and overall emissions decrease.*

Proof. See Appendix. ■

By using conditions (1)-(3), the effect of a marginal policy change by home government on the profit of home firm can be expressed as

$$\pi_t^H(\mathbf{t}) = -e^H(\mathbf{t}) + p'(X(\mathbf{t}))\, x_t^F(\mathbf{t})\, y^H(\mathbf{t}), \tag{4}$$

where $x_t^F(\mathbf{t})$ is the marginal change in profit maximizing supply of foreign firm in each market. The direct effect of a higher tax rate is the increased tax burden on each unit of emissions captured by the first term in equation (4). The second term in turn reflects the effect of a tax change on the profit of home firm through supply decisions of its rival. Since $x_t^F(\mathbf{t}) > 0$, this effect is negative in both markets. Thus, $\pi_t^H(\mathbf{t}) < 0$.

In the same manner, the effect of a marginal policy change by home government on the profit of foreign firm is

$$\pi_t^F(\mathbf{t}) = p'(X(\mathbf{t}))\, x_t^H(\mathbf{t})\, y^F(\mathbf{t}), \tag{5}$$

where $x_t^H(\mathbf{t})$ is the marginal change in profit maximizing supply of home firm in home and foreign market. As $x_t^H(\mathbf{t}) < 0$, it directly follows that $\pi_t^F(\mathbf{t}) > 0$.

Equations (4) and (5) imply that by relaxing environmental standards home government increases profits of home firm and reduces profits of its rival. These asymmetric effects of taxation enable national governments to use environmental policy to shift profits for domestic producers.

3.2 Emission Tax Competition

Consider now the problem of the national governments when they choose their tax policies non-cooperatively taking the tax policy of the other government and the equilibrium behavior of the firms as given. The objective of each government is to maximize domestic aggregate welfare which consists of profits of the national firm, consumer surplus, tax revenue, and disutility from pollution. We denote aggregate welfare in home country by w and in foreign country by w^*. Home government then chooses t so as to maximize

$$w = \pi^H(\mathbf{t}) + \int_0^X p(h)\, dh - p(X(\mathbf{t}))\, X(\mathbf{t}) + tE(\mathbf{t}) - d(E(\mathbf{t})).$$

The first-order conditions for welfare maximization, $w_t = 0$ and $w_{t^*}^* = 0$, implicitly determine equilibrium tax rates. Under the assumption that the second-order conditions for welfare maximization are satisfied, the first-order conditions determine a unique equilibrium. We denote this equilibrium by $\mathbf{t}^n = (t^n, t^{*n})$, where superscript n refers to non-cooperative outcome. Because the firms and countries are identical, $t^n = t^{*n}$.

As a result, in the non-cooperative equilibrium, the level of output and emissions are the same in the two countries, i.e. $y^H(\mathbf{t}^n) = y^F(\mathbf{t}^n)$ and $E(\mathbf{t}^n) = E^*(\mathbf{t}^n)$. Hence, the first-order condition for home government can be written as

$$\left(t^n - d'\left(E\left(\mathbf{t}^n\right)\right)\right) E_t\left(\mathbf{t}^n\right) = p'\left(X\left(\mathbf{t}^n\right)\right) x_t^H\left(\mathbf{t}^n\right) X\left(\mathbf{t}^n\right), \tag{6}$$

where in the left hand side we have the welfare-effect through a change in emissions and in the right hand side the welfare-effect through a change in supply. As $x_t^H(\mathbf{t}) < 0$, the right hand side of equation (6) is strictly positive. In addition, by Lemma 1, $E_t(\mathbf{t}) < 0$. Hence, in a symmetric non-cooperative equilibrium

$$t^{*n} = t^n < d'\left(E\left(\mathbf{t}^n\right)\right) = d'\left(E^*\left(\mathbf{t}^n\right)\right),$$

i.e. equilibrium tax rates are lower than the marginal damage caused by emissions.

3.3 Coordinated Tax Policies

We now turn to the problem of the national governments when they coordinate policies and choose emission tax rates so as to maximize joint welfare of the two countries, W. Joint welfare consists of profits of the two national firms and consumer surplus, tax revenue, and disutility of pollution in the two countries. Hence, the objective of the governments is to choose (t, t^*) so as to maximize

$$W = \pi^H(\mathbf{t}) + \pi^F(\mathbf{t}) + cs(\mathbf{t}) + cs^*(\mathbf{t}) + tE(\mathbf{t}) + t^*E^*(\mathbf{t}) - d\left(E\left(\mathbf{t}\right)\right) - d\left(E^*\left(\mathbf{t}\right)\right),$$

where

$$cs^*(\mathbf{t}) = cs(\mathbf{t}) = \int_0^X p(h)\, dh - p\left(X\left(\mathbf{t}\right)\right) X(\mathbf{t})$$

since $X^*(\mathbf{t}) = X(\mathbf{t})$ for all tax rates.

Again, under the assumption that $W_{tt} \leq 0$ and $W_{t^*t^*} \leq 0$, the first-order conditions determine a unique equilibrium denoted by $\mathbf{t}^o = (t^o, t^{*o})$, where superscript o refers to the cooperative outcome. Due to the symmetry of the countries, $t^o = t^{*o}$ and therefore,

$y^H(\mathbf{t}^o) = y^F(\mathbf{t}^o)$ and $E(\mathbf{t}^o) = E^*(\mathbf{t}^o)$. The first-order condition for home government can then be expressed as

$$(t^o - d'(E(\mathbf{t}^o)))(E_t(\mathbf{t}^o) + E_t^*(\mathbf{t}^o)) = p'(X(\mathbf{t}^o))\left(y_t^H(\mathbf{t}^o) + y_t^F(\mathbf{t}^o)\right)x^H(\mathbf{t}^o), \qquad (7)$$

where in the left hand side we have the effect of a tax increase through change in emissions and in the right hand side the effect of a tax increase through changes in supplies. Lemma 1 implies that the right hand side is strictly positive and that $E_t(\mathbf{t}) + E_t^*(\mathbf{t}) < 0$. Thus

$$t^{*o} = t^o < d'(E(\mathbf{t}^o)) = d'(E^*(\mathbf{t}^o)).$$

Not surprisingly, in the cooperative equilibrium, marginal damage of emissions is higher than emission tax rates. Complete internalization of the damage caused by emissions is not socially desirable as tightening emission control induces polluting firms with market power to further reduce suboptimally low supply.[14]

Direct comparison of the first-order conditions (6) and (7) does not reveal in what way and why the non-cooperative outcome is inefficient. In order to establish what kind of policy change would increase joint welfare of the two countries from the non-cooperative level, we evaluate W_t and W_{t^*} at the non-cooperative equilibrium.

If $W_t > 0$ and $W_{t^*} > 0$ at (t^n, t^{*n}), we conclude that a policy change introducing a marginal increase in tax rates from the non-cooperative level would increase welfare in both countries. By using equation (6) we have that at (t^n, t^{*n})

$$W_t = (t^{*n} - d'(E^*(\mathbf{t}^n)))E_t^*(\mathbf{t}^n) - p'(X(\mathbf{t}^n))x_t^F(\mathbf{t}^n)X(\mathbf{t}^n), \qquad (8)$$

which consists of three different welfare-effects that home government imposes on foreign consumers when it tightens emission taxation. First, a higher tax rate in home country increases emissions and tax revenue in foreign country. Since $t^{*n} < d'(E^*(\mathbf{t}^n))$, this reduces welfare of foreign consumers. Second, an increase in t induces home firm to cut down production and reduce supply in both markets. This increases profits for foreign firm but reduces consumer surplus in foreign country. In a symmetric equilibrium these

[14] This is the same mechanism, unrelated to regulatory competition, as in Barnett (1980). See also Kennedy (1994).

two effects cancel each other. Third, the supply expansion by foreign firm increases consumer surplus in foreign country. This positive effect is captured by the last term in equation (8).

Consequently, an increase in t has a negative effect on foreign welfare through increased emissions but a positive effect through larger consumer surplus. However, it can be shown that in the non-cooperative equilibrium, the relative size of these two effects is such that

Proposition 1 *When the two countries are occupied by national firms, setting policies non-cooperatively leads to too lax emission regulation.*

Proof. See Appendix. ■

The non-cooperative tax rates are lower than cooperative tax rates that maximize the joint welfare of the two countries. From Lemma 1 it then also follows that level of emissions in both countries and supply in both markets are higher in the non-cooperative equilibrium than when decisions on taxation are taken in a coordinated manner.

4 Tax Policy and Multinational Firms

In this section, we consider multinational firms that have production plants in both countries. The crucial difference with the previous analysis is that multinational firms are able to react to policy changes not only by adjusting supply and abatement levels, but also by shifting production from one country to another. As in the previous section, we assume that home firm is entirely owned by consumers in home country and foreign firm is owned by foreign consumers.

We proceed as in section 3 by first solving the profit maximization problems of the firms and then considering policy design.

4.1 Multinational Firms

Given emission taxes (t, t^*) set by the national governments, profit maximization problem of firm j is

$$\max_{y^j, a^j, y^{*j}, a^{*j}, i^j} \pi^j = p\left(X\right) x^j + p\left(X^*\right) x^{*j} - c\left(y^j\right) - g\left(a^j\right) - te^j - c\left(y^{*j}\right) - g\left(a^{*j}\right) - t^* e^{*j},$$

where firm j's output in home country is y^j and output in foreign country y^{*j}. Supply in home market is $x^j = y^j + i^j$ and supply in foreign market is $x^{*j} = y^{*j} - i^j$. The first-order conditions for profit maximization for home firm are

$$\frac{\partial \pi^H}{\partial y^H} = p'\left(X\right) x^H + p\left(X\right) - c'\left(y^H\right) - t = 0, \tag{9}$$

$$\frac{\partial \pi^H}{\partial a^H} = t - g'\left(a^H\right) = 0, \tag{10}$$

$$\frac{\partial \pi^H}{\partial y^{*H}} = p'\left(X^*\right) x^{*H} + p\left(X^*\right) - c'\left(y^{*H}\right) - t^* = 0, \tag{11}$$

$$\frac{\partial \pi^H}{\partial a^{*H}} = t^* - g'\left(a^{*H}\right) = 0, \tag{12}$$

$$\frac{\partial \pi^H}{\partial i^H} = p'\left(X\right) x^H + p\left(X\right) - p'\left(X^*\right) x^{*H} - p\left(X^*\right) = 0. \tag{13}$$

The first-order conditions for foreign firm are again analogous. Together these conditions imply that multinational firms choose levels of output, abatement, and imports so that marginal production cost equals marginal revenue, marginal abatement cost equals emission tax rate, and marginal revenues from the two markets are equalized. As in the case of national firms, we denote the optimal output, supply, and abatement levels as a function of the tax rates for firm j by $y^j\left(\mathbf{t}\right)$, $y^{*j}\left(\mathbf{t}\right)$, $x^j\left(\mathbf{t}\right)$, etc. Due to identical demand conditions in the two countries, we again have that $x^{*j}\left(\mathbf{t}\right) = x^j\left(\mathbf{t}\right)$ for $j = H, F$ and consequently $X^*\left(\mathbf{t}\right) = X\left(\mathbf{t}\right)$.

From the first-order conditions we can deduce that

Lemma 2 *When home government tightens emission control, both multinational firms cut back on production in home country and increase production in foreign country. Both firms reduce supply in both markets. Emissions decrease in home country and increase in foreign country. Overall emissions decrease.*

Proof. See Appendix. ■

Comparison with Lemma 1 shows that regardless of whether firms are national or multinational, aggregate supply in both markets and overall emissions decrease when either of the governments tightens emission control. The difference is that multinational firms react symmetrically to any policy change. Assume, for instance, that home government tightens pollution control. If the firms are national, foreign firm increases and home firm reduces supply in both markets. If the firms are multinational, both firms reduce supply in both markets.

Lemma 2 implies that the two multinational firms always produce equal output in their plants located in the same country, i.e. $y^H(\mathbf{t}) = y^F(\mathbf{t})$ and $y^{*H}(\mathbf{t}) = y^{*F}(\mathbf{t})$. Hence, $x^H(\mathbf{t}) = x^F(\mathbf{t})$ and the effects of an increase in the tax rate in home country on the profits are

$$\pi_t^H(\mathbf{t}) = -e^H(\mathbf{t}) + p'(X(\mathbf{t}))\, x_t^F(\mathbf{t}) \left(y^H(\mathbf{t}) + y^{*H}(\mathbf{t})\right) \tag{14}$$

and

$$\pi_t^F(\mathbf{t}) = -e^F(\mathbf{t}) + p'(X(\mathbf{t}))\, x_t^H(\mathbf{t}) \left(y^F(\mathbf{t}) + y^{*F}(\mathbf{t})\right), \tag{15}$$

where the first term is the increased tax burden on each unit of emissions. The second term is the indirect effect of a policy change through supply decisions of the rival firm. When emission taxation becomes stricter in home country, both firms increase production in their plant located in foreign country but reduce supply in both markets. This implies that using environmental policy to increase market share of the domestic producer is not feasible when firms are multinational.

When the firms are multinational, in each country there is a production plant that belongs to a firm that is owned by foreign shareholders. Had the national governments the possibility, they would tax more severely emissions generated by the plant in foreign ownership. Hence, the restriction that national governments cannot discriminate between the firms, but are constrained to set a uniform emission tax rate that applies to all firms operating within the country, plays a crucial role.

4.2 Emission Tax Competition

We now analyze the design of emission taxation when the national governments act non-cooperatively taking the policy of the other government and the equilibrium behavior of the polluting firms as given. The countries are again symmetric, and we will mainly focus on home government. Each government chooses its tax policy to maximize domestic aggregate welfare taking the policy of the other government as given. The objective of home government is thus to choose t so as to maximize

$$w = cs\left(\mathbf{t}\right) + \pi^{H}\left(\mathbf{t}\right) + tE\left(\mathbf{t}\right) - d\left(E\left(\mathbf{t}\right)\right),$$

and the objective of foreign government is to choose t^* so as to maximize

$$w^* = cs^*\left(\mathbf{t}\right) + \pi^{F}\left(\mathbf{t}\right) + t^*E^*\left(\mathbf{t}\right) - d\left(E^*\left(\mathbf{t}\right)\right).$$

Under the assumption that the second-order conditions are satisfied, the first-order conditions, $w_t = 0$ and $w^*_{t^*} = 0$, again determine a unique non-cooperative equilibrium, $\mathbf{t}^n = (t^n, t^{*n})$. Since the firms and countries are identical and the ownership structure of the multinational firms is symmetric, $t^n = t^{*n}$. Thus, in equilibrium the output of each firm is the same in the two plants and emission levels in the two countries are equal, i.e. $y^H\left(\mathbf{t}^n\right) = y^{*H}\left(\mathbf{t}^n\right)$ and $e^H\left(\mathbf{t}^n\right) = e^{*H}\left(\mathbf{t}^n\right)$. Then, by taking into account (14) and (15), the equilibrium condition for home government can be written as

$$\left(t^n - d'\left(E\left(\mathbf{t}^n\right)\right)\right) E_t\left(\mathbf{t}^n\right) - p'\left(X\left(\mathbf{t}^n\right)\right) x_t^F\left(\mathbf{t}^n\right) X\left(\mathbf{t}^n\right) + e^H\left(\mathbf{t}^n\right) = 0. \tag{16}$$

The first term in condition (16) is the welfare-effect of a change in emissions. The second term reflects the welfare-effect of a tax increase through market price. This term is negative as the negative effect of a reduction in output on consumer surplus dominates the positive effect on profits. The last term reflects the effect of increased tax revenue from foreign owners of the multinational firms and is strictly positive. Hence,

$$t^{*n} = t^n \gtreqless d'\left(E\left(\mathbf{t}^n\right)\right) = d'\left(E^*\left(\mathbf{t}^n\right)\right),$$

and we have that

Lemma 3 *For multinational firms, non-cooperative tax rates may be higher or lower than the marginal damage of emissions depending on whether the positive effect of*

increased tax revenue from owners of the foreign multinational firm or the negative effect of reduced consumer surplus dominates.

Proof. Follows directly from equation (16) and Lemma 2. ■

Equilibrium tax rates may exceed marginal damage of emissions because setting a higher tax rate yields increased tax revenue from foreign shareholders of the multinational firms.

4.3 Coordinated Tax Policies

We now turn to the situation where the governments coordinate tax policies in order to maximize joint welfare of the two countries which consists of consumer surplus in the two countries, profits of the firms, tax revenues and disutility from pollution. Hence, under coordination, the governments choose t and t^* so as to maximize

$$W = cs(\mathbf{t}) + cs^*(\mathbf{t}) + \pi^H(\mathbf{t}) + \pi^F(\mathbf{t}) + tE(\mathbf{t}) - d(E(\mathbf{t})) + t^*E^*(\mathbf{t}) - d(E^*(\mathbf{t})).$$

As in the previous cases studied, under the assumption that the second-order conditions are satisfied, the first-order conditions determine a unique cooperative equilibrium $\mathbf{t}^o = (t^o, t^{*o})$ with $t^o = t^{*o}$. Therefore, $y^H(\mathbf{t}^o) = y^{*H}(\mathbf{t}^o)$ and $e^{*H}(\mathbf{t}^o) = e^H(\mathbf{t}^o)$. Thus, taking into account (14) and (15), the first-order condition for home government can be written as

$$(t^o - d'(E(\mathbf{t}^o)))(E_t(\mathbf{t}^o) + E_t^*(\mathbf{t}^o)) = p'(X(\mathbf{t}^o))\left(x_t^F(\mathbf{t}^o) + x_t^H(\mathbf{t}^o)\right)X(\mathbf{t}^o). \qquad (17)$$

Since $x_t^H(\mathbf{t}) < 0$ and $x_t^F(\mathbf{t}) < 0$, the right hand side is strictly positive. Furthermore, $(E_t(\mathbf{t}) + E_t^*(\mathbf{t})) < 0$. Therefore, it readily follows that

$$t^{*o} = t^o < d'(E(\mathbf{t}^o)) = d'(E^*(\mathbf{t}^o)).$$

While non-cooperative tax rates may be higher than the marginal damage of emissions, coordinated tax rates are always lower than the marginal damage. The reason is the

same as when the firms are national. Completely internalizing the negative effects of emissions is not socially beneficial as it would lead to too large reductions in supply.

As in the case of national firms, we wish to analyze the relationship of the non-cooperative and coordinated outcome. In order to compare the outcome when the governments set their policies in a non-cooperative manner and when they coordinate policies, we again evaluate W_t at the non-cooperative equilibrium. By using equation (16), we have that W_t evaluated at (t^n, t^{*n}) is

$$W_t = -p'\left(X\left(\mathbf{t}^n\right)\right)\left[X_t\left(\mathbf{t}^n\right) - x_t^H\left(\mathbf{t}^n\right)\right]X\left(\mathbf{t}^n\right) + \left(t^{*n} - d'\left(E^*\left(\mathbf{t}^n\right)\right)\right)E_t^*\left(\mathbf{t}^n\right) - e^H\left(\mathbf{t}^n\right) \tag{18}$$

where the right hand side reflects all the effects of tighter emission taxation in home country on the welfare of foreign consumers. First, when home government increases emission tax, both firms reduce supply in foreign market. This increases market price reducing consumer surplus and increasing profits. The negative effect on consumer surplus dominates the positive effect on profits. This effect is captured by the first term in (18). Second, when home government increases its emission tax, emissions in foreign country increase. The second term in equation (18) reflects the welfare-effect of increased emissions in foreign country. If $t^{*n} < d'\left(E^*\left(\mathbf{t}^n\right)\right)$ this effect is negative. Finally, the last term captures the effect of a higher tax rate on foreign owners of multinational firms in the form of increased tax burden on each unit of emissions generated in their plant located in home country. This effect is always negative. Hence, if $t^{*n} < d'\left(E^*\left(\mathbf{t}^n\right)\right)$, all these welfare-effects are negative.

However, it can be shown that even if $t^{*n} > d'\left(E^*\left(\mathbf{t}^n\right)\right)$, the positive effect of increased tax revenue net of environmental damage never dominates the negative effects that a higher tax rate in home country has on welfare in foreign country. Hence,

Proposition 2 *When the two countries are occupied by multinational firms, setting emission taxation non-cooperatively leads to excessively severe taxation.*

Proof. See Appendix. ■

The non-cooperative tax rates are higher than cooperative tax rates that maximize the joint welfare of the two countries. Lemma 2 then implies that also the level of

emissions in both countries is lower and supply in both markets is smaller in the non-cooperative equilibrium than when decisions on taxation are taken in a coordinated manner. As the multinational firms react in the same way to any policy change, policy changes do not influence the market shares of the firms. Hence, the main motive for relaxing environmental taxation when firms are national does not exist when they are multinational. Furthermore, the existence of a foreign production plant in each country creates an incentive to tax foreign owners of multinational firms. As a result, coordination of environmental policies would increase welfare in both countries and would call for a reduction in emission tax rates from the non-cooperative level.

5 Conclusions

The literature on strategic environmental policy exhibits well known results on non-cooperative environmental policy setting when polluting firms are national. In this paper, we have extended this analysis to a situation of multinational production where polluting firms are able to move production from one country to another as a reaction to government policies. We showed that the incentives of national governments change for environmental regulation in two important ways when the firms are multinational as opposed to being national.

First, national polluting firms react asymmetrically to any policy change by national governments. For instance, tightening emission control in home country induces foreign firm to expand supply and home firm to cut down supply in both markets. These asymmetric reactions to policy changes enable governments to use environmental policy as a means to increase the market share of the domestic firm and the profits of the domestic shareholders. Multinational firms, in contrast, react in the same way to any policy change. A higher tax rate in one country induces both firms to shift production to the other country and to reduce overall production. Consequently, relaxing emission taxation is not useful in shifting profits to domestic shareholders as changes in taxation do not influence market shares of the firms.

Second, when polluting firms are multinational, in each country there is a production plant that is in foreign ownership. When setting policies, national governments ignore profits that accrue to foreign shareholders of these plants and are thus inclined to

set too severe emission taxation. As a result, while non-cooperative taxation is too lax when firms are national, it is too severe when firms are multinational. Relaxing emission taxation from the non-cooperative level in both countries would unambiguously increase welfare in the two countries. Of course, environmental regulation may be too lax for reasons not accounted for in this analysis, but the ability of the firms to react to policy changes by moving production from one country to another does not seem to aggravate the problem.

It is useful to note though that here the national governments have several objectives: they want to limit the negative effects of harmful emissions, they care about the profits of domestic shareholders and domestic consumer surplus, and, when the firms are multinational, they also wish to tax profits accruing to foreign shareholders. But the only instrument available to the national governments is emission taxation. This assumption is motivated by the existence of international agreements that restrict the possibilities of governments to use direct trade policy measures or to discriminate between production plants on the basis of their ownership. If, in contrast, the governments had a portfolio of instruments available, environmental policy would not necessarily be used for all the purposes mentioned above in which case the need for coordination might not exist. In addition, as is well known from previous literature, the policy conclusions of the strategic trade policy model when firms are national depend on the mode of competition in the oligopolistic market. Whether this is true also when firms are multinational is a topic for further research.

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A Appendix

Proof of Lemma 1. As the markets are identical, $x^j(\mathbf{t}) = x^{*j}(\mathbf{t})$ for $j = H, F$. Given this, let us denote profits of firm j by $\pi^j\left(y^H, y^F\right)$. Totally differentiating the first-order conditions of home firm gives

$$\frac{dy^H}{dt} = \frac{\pi^F_{22}}{D}, \frac{dy^H}{dt^*} = -\frac{\pi^F_{21}}{D}, \text{ and } \frac{da^H}{dt} = \frac{1}{g''(a^H)},$$

where

$$D = \pi^H_{11}\pi^F_{22} - \pi^F_{21}\pi^H_{12} > 0.$$

From these relations it then follows that

$$\frac{de^H}{dt} < \frac{dy^H}{dt} < 0, \frac{dx^{*H}}{dt} = \frac{dx^H}{dt} < 0, \text{ and } \frac{de^H}{dt^*} = \frac{dy^H}{dt^*} > 0, \frac{dx^H}{dt^*} = \frac{dx^{*H}}{dt^*} > 0.$$

Since $\pi^F_{22} < \pi^F_{21} < 0$, it also follows that $\frac{d\left(y^H+y^F\right)}{dt} < 0$. ■

Proof of Proposition 1. The first-order condition for foreign government can be written as

$$\left(t^{*n} - d'\left(E^*\left(\mathbf{t}^n\right)\right)\right) = \frac{p'\left(X\left(\mathbf{t}^n\right)\right) x^F_{t^*}\left(\mathbf{t}^n\right) X\left(\mathbf{t}^n\right)}{E^*_{t^*}\left(\mathbf{t}^n\right)}.$$

Substituting this expression for $t^{*n} - d'\left(E^*\left(\mathbf{t}^n\right)\right)$ in (8) yields

$$\begin{aligned} W_t &= \frac{p'\left(X\left(\mathbf{t}^n\right)\right) x^F_{t^*}\left(\mathbf{t}^n\right) X\left(\mathbf{t}^n\right) E^*_t\left(\mathbf{t}^n\right)}{E^*_{t^*}\left(\mathbf{t}^n\right)} - p'\left(X\left(\mathbf{t}^n\right)\right) x^F_t\left(\mathbf{t}^n\right) X\left(\mathbf{t}^n\right) \\ &= p'\left(X\left(\mathbf{t}^n\right)\right) X\left(\mathbf{t}^n\right) E^*_t\left(\mathbf{t}^n\right) \left[\frac{x^F_{t^*}\left(\mathbf{t}^n\right)}{E^*_{t^*}\left(\mathbf{t}^n\right)} - \frac{x^F_t\left(\mathbf{t}^n\right)}{E^*_t\left(\mathbf{t}^n\right)}\right], \end{aligned}$$

where the part before the square brackets is negative as $p'\left(X\left(\mathbf{t}^n\right)\right) < 0$ and $E_t^*\left(\mathbf{t}^n\right) > 0$. When firms are national, $E^*\left(\mathbf{t}\right) = e^F\left(\mathbf{t}\right) = y^F\left(\mathbf{t}\right) - a^F\left(\mathbf{t}\right)$. Furthermore, since $y^F\left(\mathbf{t}\right) = 2x^F\left(\mathbf{t}\right)$ it follows that

$$E_t^*\left(\mathbf{t}^n\right) = 2x_t^F\left(\mathbf{t}^n\right) - a_t^F\left(\mathbf{t}\right) \text{ and } E_{t^*}^*\left(\mathbf{t}^n\right) = 2x_{t^*}^F\left(\mathbf{t}^n\right) - a_{t^*}^F\left(\mathbf{t}\right),$$

where $a_t^F\left(\mathbf{t}\right) = 0$ and $a_{t^*}^F\left(\mathbf{t}\right) > 0$. Consequently,

$$0 < \frac{x_{t^*}^F\left(\mathbf{t}^n\right)}{E_{t^*}^*\left(\mathbf{t}^n\right)} < \frac{x_t^F\left(\mathbf{t}^n\right)}{E_t^*\left(\mathbf{t}^n\right)}$$

and the term inside the square brackets is negative. Hence, evaluated at the non-cooperative equilibrium, $W_t > 0$. ■

Proof of Lemma 2. Again $x^j\left(\mathbf{t}\right) = x^{*j}\left(\mathbf{t}\right)$ for $j = H, F$. Let us denote the profit function for firm j by $\pi^j\left(y^H, y^{*H}, y^F, y^{*F}\right)$. By totally differentiating first-order conditions (9), (12), and the corresponding first-order conditions for foreign firm then gives

$$\begin{bmatrix} \pi_{11}^H & \pi_{12}^H & \pi_{13}^H & \pi_{14}^H \\ \pi_{21}^H & \pi_{22}^H & \pi_{23}^H & \pi_{24}^H \\ \pi_{31}^F & \pi_{32}^F & \pi_{33}^F & \pi_{34}^F \\ \pi_{41}^F & \pi_{42}^F & \pi_{43}^F & \pi_{44}^F \end{bmatrix} \begin{bmatrix} dy^H \\ dy^{*H} \\ dy^F \\ dy^{*F} \end{bmatrix} = \begin{bmatrix} dt \\ dt^* \\ dt \\ dt^* \end{bmatrix}$$

Taking into account Assumptions 1 and 2 implies that

$$\pi_{11}^H = \pi_{22}^H = \pi_{33}^F = \pi_{44}^F$$

and $\pi_{11}^H < \pi_{12}^H < \pi_{13}^H < 0$. Furthermore, $\pi_{kh}^H = \pi_{hk}^F$ where $k = 1, 2$ and $h = 3, 4$ and $\pi_{12}^H = \pi_{21}^H = \pi_{34}^F = \pi_{43}^F$. Consequently,

$$\frac{dy^H}{dt} = \frac{C}{D} < 0 \text{ and } \frac{dy^H}{dt^*} = \frac{E}{D} > 0,$$

where

$$\begin{aligned} D &= \left(\pi_{11}^H - \pi_{12}^H\right)\left(\underbrace{\left(\pi_{11}^H + \pi_{22}^H\right)^2 - \left(2\pi_{13}^H\right)^2}_{+}\right) < 0, \\ C &= \underbrace{\left(\pi_{11}^H + \pi_{13}^H\right)}_{-}\left(\underbrace{\pi_{11}^H - \pi_{13}^H}_{-} + \underbrace{\pi_{12}^H - \pi_{13}^H}_{-}\right) > 0 \text{ and} \\ E &= -\underbrace{\left(\pi_{12}^H + \pi_{13}^H\right)}_{-}\left(\underbrace{\pi_{11}^H - \pi_{13}^H}_{-} + \underbrace{\pi_{12}^H - \pi_{13}^H}_{-}\right) < 0. \end{aligned}$$

In addition,

$$\frac{da^H}{dt} = \frac{1}{g''\left(a^H\right)} > 0 \text{ and } \frac{da^{*H}}{dt} = 0.$$

From the above relations it follows that

$$\frac{de^H}{dt} < \frac{dx^H}{dt} < 0, \frac{dy^{*H}}{dt} = \frac{de^{*H}}{dt} > 0, \text{ and } \frac{di^H}{dt} > 0.$$

As the firms are identical, $y^{*F}(\mathbf{t}) = y^{*H}(\mathbf{t})$ and $y^F(\mathbf{t}) = y^H(\mathbf{t})$. Using the above relations for home and foreign firm then implies that

$$\frac{d\left(E + E^*\right)}{dt} < 0, \frac{dX}{dt} < 0, \text{ and } \frac{dX^*}{dt} < 0.$$

■

Proof of Proposition 2. The first-order condition for foreign government can be written as

$$\begin{aligned} t^{*n} - d'\left(E^*\left(\mathbf{t}^n\right)\right) &= \frac{p'\left(X\left(\mathbf{t}^n\right)\right)\left[X_{t^*}\left(\mathbf{t}^n\right) - x_{t^*}^H\left(\mathbf{t}^n\right)\right]X\left(\mathbf{t}^n\right) - e^{*H}\left(\mathbf{t}^n\right)}{E_{t^*}^*\left(\mathbf{t}^n\right)} \\ &= \frac{p'\left(X\left(\mathbf{t}^n\right)\right)x_{t^*}^F\left(\mathbf{t}^n\right)X\left(\mathbf{t}^n\right) - e^{*H}\left(\mathbf{t}^n\right)}{E_{t^*}^*\left(\mathbf{t}^n\right)} \end{aligned} \tag{A1}$$

where the second equality uses $x_{t^*}^F(\mathbf{t}) = x_{t^*}^H(\mathbf{t})$. Let

$$\begin{aligned} \kappa &= \frac{E_t^*\left(\mathbf{t}^n\right)}{E_{t^*}^*\left(\mathbf{t}^n\right)} = \frac{y_t^{*H}\left(\mathbf{t}^n\right) - a_t^{*H}\left(\mathbf{t}^n\right) + y_t^{*F}\left(\mathbf{t}^n\right) - a_t^{*F}\left(\mathbf{t}^n\right)}{y_{t^*}^{*H}\left(\mathbf{t}^n\right) - a_{t^*}^{*H}\left(\mathbf{t}^n\right) + y_{t^*}^{*F}\left(\mathbf{t}^n\right) - a_{t^*}^{*F}\left(\mathbf{t}^n\right)} \\ &= \frac{y_t^{*F}\left(\mathbf{t}^n\right) + y_t^{*H}\left(\mathbf{t}^n\right)}{y_{t^*}^{*H}\left(\mathbf{t}^n\right) - a_{t^*}^{*H}\left(\mathbf{t}^n\right) + y_{t^*}^{*F}\left(\mathbf{t}^n\right) - a_{t^*}^{*F}\left(\mathbf{t}^n\right)}, \end{aligned}$$

where the last equality follows from $a_t^{*H}(\mathbf{t}^n) = a_t^{*F}(\mathbf{t}^n) = 0$. From Lemma 2 it follows that $a_{t^*}^{*H}(\mathbf{t}^n) > 0$, $a_{t^*}^{*F}(\mathbf{t}^n) > 0$, $y_t^{*H}(\mathbf{t}^n) = y_t^{*F}(\mathbf{t}^n) > 0$, and $y_{t^*}^{*H}(\mathbf{t}^n) = y_{t^*}^{*F}(\mathbf{t}^n) < 0$. Furthermore, since the production cost function is convex, $y_t^{*H}(\mathbf{t}^n) + y_{t^*}^{*H}(\mathbf{t}^n) < 0$. Consequently,

$$-1 < \kappa < 0. \tag{A2}$$

Substituting (A1) for $t^{*n} - d'(E^*(\mathbf{t}^n))$ in (18) yields

$$\begin{aligned} W_t &= -p'(X(\mathbf{t}^n))\, x_t^F(\mathbf{t}^n)\, X(\mathbf{t}^n) + \frac{p'(X(\mathbf{t}^n))\, x_{t^*}^F(\mathbf{t}^n)\, X(\mathbf{t}^n) - e^{*H}(\mathbf{t}^n)}{E_{t^*}^*(\mathbf{t}^n)} E_t^*(\mathbf{t}^n) - e^H(\mathbf{t}^n) \\ &= -p'(X(\mathbf{t}^n))\, X(\mathbf{t}^n) \left[x_t^F(\mathbf{t}^n) - x_{t^*}^F(\mathbf{t}^n)\,\kappa\right] - e^H(\mathbf{t}^n)\,[\kappa + 1], \end{aligned}$$

where the second equality uses $e^{*H}(\mathbf{t}^n) = e^H(\mathbf{t}^n)$. Since $p'(X(\mathbf{t})) < 0$, $x_t^F(\mathbf{t}) < 0$, and $x_{t^*}^F(\mathbf{t}) < 0$, taking into account (A2) shows that $W_t < 0$ in the non-cooperative equilibrium. ■

Essay III

International Trade Agreements, Environmental Policy, and Emergence of Multinational Firms

Abstract

During recent decades there has been substantial momentum for trade liberalization. At the same time, environmental policy has largely remained at the discretion of national governments. This paper studies how free trade agreements influence national environmental policies and location strategies of polluting firms. When the national governments cannot use direct trade policy measures, environmental policy is distorted towards enhancing the competitiveness of domestic producers. When this is the case, signing agreements that prevent the use of trade policy may lead to firms investing in production capacity abroad.

Keywords: Environmental policy, foreign direct investment, multinational production, trade agreements

JEL Classification: H23, H77, F18, F23

1 Introduction

During the last few decades multinational firms have become increasingly important in international competition. The emergence of multinational firms has been followed by a substantial theoretical and empirical literature analyzing the rationale for multinational production. The starting point of this literature has been that since operating in a foreign country will necessarily incur some cost, becoming multinational must bring some off-setting advantages.

An organizing framework for studying the benefits of multinational production has been the OLI framework, according to which multinational production will take place if three prerequisites, ownership, location, and internalization advantages, are satisfied.[1] For instance, Horstman and Markusen (1992) and Brainard (1993) show in a setting of identical countries that horizontal multinational firms are more likely to arise if plant-level fixed costs are low and firm-level fixed costs and transportation costs are high. Devereux and Hubbard (2000) extend the set-up to study the effect of different corporate tax systems on outbound investment when the tax system in the host country of the investment is given. Markusen and Venables (1998, 2000) study heterogenous countries and further show that multinational production occurs when countries are similar in size as well as in relative factor endowment. Some recent papers study endogenous industry structures in a setting where both horizontal and vertical multinational firms may emerge. See e.g. Markusen and Maskus (2001a, 2001b).[2] In short, vertical multinational production would emerge especially in situations where countries under study have very different relative factor endowments and trade costs, including tariffs and other methods of protectionism, are low. These findings lie in conformity with empirical evidence on multinational production.[3]

An important source of the location advantage is government policies, obvious examples being tariffs and investment barriers.[4] In addition to these, the potential effect

[1] See e.g. Markusen (1995, 1998).

[2] An early contribution on vertical multinational firms is Helpman (1984).

[3] See e.g. Markusen (1998).

[4] National policy design is the only reason for becoming multinational, for instance, in Janeba (2000). There, investing in production capacity in two countries may be profitable if a firm wishes to protect itself against time inconsistent governments that would otherwise confiscate all profits after

of environmental regulation on production and location decisions of firms has received a lot of attention. Empirical literature on how stringent environmental regulation affects the location of polluting industries is abundant but the evidence remains mixed. Most studies reject the so-called pollution haven hypothesis which states that polluting industries leave countries with stringent environmental regulation and move to countries with lax environmental regulation. Levinson (1996) studies location decisions of domestic firms in the US and finds little evidence that stringent regulations deter new plants from opening. List and Co (2000) in turn study the effect of heterogenous environmental regulations in the US states for plant location decisions of foreign multinational firms, and conclude that stringent environmental regulation and attractiveness of location are inversely related. Antweiler et al. (2001) study the effect of reduced trade costs on the location of polluting activities in a setting where the factor endowment motivation and the pollution haven motivation for the location of polluting production balance one another.[5]

Early theoretical studies linking environmental policy and competitiveness focus on the effects of stringent environmental regulation on the production costs of domestic industries, see e.g. Pethig (1976) and McGuire (1982). Markusen (1997) also considers the effect of environmental regulation on the production costs of firms but studies how the decision of national firms to remain national or become multinational is affected by strict environmental regulation. Also in Markusen et al. (1995) multinational production may arise as a single firm must decide whether to set up a production plant in two countries or in one country only. The trade-off for the firm is between transportation costs and plant-level fixed costs. Markusen et al. analyze non-cooperative policy design of two governments and consider two cases: 1) the firm first chooses the location of production and the governments then choose policies and 2) policies are chosen before location of production. They then compare welfare and pollution levels in the two countries in these two cases.

This paper considers the role of environmental policy for multinational production from a different perspective. The starting point of the paper is the observation that there has been increasing pressure towards trade liberalization through international

investment has been sunk.

[5]Jaffe et al. (1995) surveys earlier literature.

agreements, for instance, within the WTO and its predecessor the GATT, while environmental policy has largely remained at the discretion of national governments. We study how this change in the international regime may influence multinational production. We do not consider the direct effects of trade agreements, like the reduction of trade and investment barriers, which have received a lot of attention in the literature. Instead, we study the indirect effects of a trade agreement that prevents the use of export subsidies through changes in other areas of policy, namely in the design of national environmental policies. The main questions of interest are the following: First, how does national policy design influence firms' incentives to invest in production capacity in a foreign country? Second, how does the change in the international institutional regime affect the role of policy design?

In order to address this issue, we build a two country model with two polluting firms in the spirit of the strategic trade policy literature introduced by Brander and Spencer (1985).[6] Initially each firm is established in one country, has two production plants, and sells its product to a third market. The firms can invest abroad by closing one plant in their home country and opening a new plant abroad. We analyze the incentives of the firms to do that under two different regimes. Under the first regime, national governments may use both export subsidies and environmental policy. Under the second regime, a trade agreement prohibits the use of export subsidies. When using environmental policy, the national governments are constrained to set a uniform tax rate on all polluting plants within their territory.[7]

Our main result is that a change in the international regime that restricts the instrument set available to the national governments may increase the attractiveness of multinational production. When the governments are constrained not to use subsidies to the domestic producer, the firms are more likely to invest abroad. The reason is that when the governments cannot use export subsidies and the firms are national, governments use environmental policy not only to correct the negative externality caused by production but also to shift profits to domestic shareholders. In this situation, opening a production plant abroad affects the policy of the host government in two ways. For-

[6] Walz and Wellisch (1997) and Tanguay (2001) use the same set-up to study the welfare effects of free trade agreements that prevent the use of export subsidies in a setting of national, immobile firms.

[7] This would be the case, for instance, within the EU single market.

eign owned plants not only eliminate the possibility to use environmental policy to shift profits to domestic shareholders but also create an incentive to tax profits accruing to foreign shareholders. In contrast, when the governments can use both environmental and trade policy, an investment abroad does not have similar strategic effects.

The paper is organized as follows. Section 2 presents the model. In sections 3 and 4 we solve the equilibrium policies and industry structure. Section 5 concludes.

2 The Model

We develop a model of two identical countries, home and foreign, and a polluting industry consisting of two firms, home (H) and foreign (F). Each firm has two production plants and sells its product to a third market. When the firms are national, the two production plants of each firm are located in one country. When the firms are multinational, each firm has one plant in home and one in foreign country. Total output of firm i, y^i, is

$$y^i = x^i + x^{*i},$$

where $i = H, F$ and x is plant level production. If firm i is multinational, x^i refers to production in home country and x^{*i} refers to production in foreign country. Aggregate supply is $Y = y^H + y^F$ and revenue of firm i is

$$p\left(Y\right) y^i,$$

where $p\left(Y\right)$ is the inverse demand function in the third market. Throughout the paper we assume that:

Assumption 1 *Demand function satisfies*

$$p''\left(Y\right) y^i + p'\left(Y\right) < 0 \text{ for } i = H, F.$$

Same abatement technology is available for the firms in both countries. We normalize units of emission so that emissions generated by firm i are

$$\left(x^i - q^i\right) + \left(x^{*i} - q^{*i}\right),$$

where q^i and q^{*i} are the abatement levels of firm i in its two plants. In the case that firm i is multinational, $(x^i - q^i)$ refers to emissions generated in home country and $(x^{*i} - q^{*i})$ to emissions generated in foreign country. Level of emissions in home country is denoted by E and in foreign country by E^*. Environmental damage caused by emissions is $d(E)$ in home country and $d(E^*)$ in foreign country.

Trade policy takes the form of export subsidies for the domestic producer. Environmental policy, in turn, consists of choosing emission tax levied on the firms. Each government levies a tax on emissions generated in its own country and cannot discriminate between firms according to their ownership. Tax revenues are distributed back to consumers as lump sum transfers. We consider policy design under two different regimes. Under the first regime, national governments may use both trade and environmental policies. Under the second regime, a trade agreement between the two countries prevents them from using export subsidies.

Investment abroad in the form of opening a production plant in a foreign country and closing a plant in home country must entail some cost for the investing firm. We represent all the costs related to this investment by a fixed cost G for both firms. Empirical evidence suggests that multinational firms exist in industries with high firm-level fixed costs and low plant-level fixed costs. We assume that the firm-level and plant-level fixed costs and the size of the export market are such that only two firms exist in the market. Therefore, we consider explicitly only plant-level fixed costs. We also assume that there are no transportation costs.[8]

There are four possible industry structures denoted by $j \in \{nn, mm, nm, mn\}$, where n denotes national and m multinational firm, and $j = nm$ refers to the industry structure where home firm is national and foreign firm is multinational. As all results will be symmetric when $j = nm$ and $j = mn$, we study policy design only under industry structures $j = nn$, $j = mm$, and $j = nm$.

Under industry structure j, total variable costs of firm i are

$$C^i\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) = c\left(x^i\right) + c\left(x^{*i}\right) + g\left(q^i\right) + g\left(q^{*i}\right) + \gamma^i\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) \tag{1}$$

[8] This assumption is made to simplify the analysis. We will comment on how it affects the results in section 4.2.

where $\mathbf{u} = (t, t^*, s, s^*)$ is the vector of policy variables. Terms t and t^* are the emission tax rates in home and foreign country. Terms s and s^* in turn are the export subsidies for the domestic firm in home and foreign country. The first two terms in (1) denote the cost of production in each plant. The two following terms denote the cost of emission abatement in each plant. The last term in (1) is the total tax burden of the firm and depends on the location of its production plants. For home firm

$$\begin{aligned}\gamma^H\left(\mathbf{u}; x^H, x^{*H}, q^H, q^{*H}; nn\right) &= \gamma^H\left(\mathbf{u}; x^H, x^{*H}, q^H, q^{*H}; nm\right) \\ &= t\left(x^H - q^H\right) + t\left(x^{*H} - q^{*H}\right) - s\left(x^H + x^{*H}\right)\end{aligned}$$

and

$$\begin{aligned}\gamma^H\left(\mathbf{u}; x^H, x^{*H}, q^H, q^{*H}; mm\right) &= \gamma^H\left(\mathbf{u}; x^H, x^{*H}, q^H, q^{*H}; mn\right) \\ &= t\left(x^H - q^H\right) + t^*\left(x^{*H} - q^{*H}\right) - s\left(x^H + x^{*H}\right).\end{aligned}$$

We will assume that:

Assumption 2 *All cost functions are strictly convex, i.e.* $c'(\cdot) > 0$, $c''(\cdot) > 0$, $g'(\cdot) > 0$, $g''(\cdot) > 0$, $d'(\cdot) > 0$, and $d''(\cdot) > 0$.

We use convex production costs in order to rule out the unrealistic event that when firms are multinational, a marginal change in environmental policy induces firms to shift all production from one country to another.[9]

Timing of the events is as follows. The firms first decide whether to remain national or to invest abroad. Investing abroad implies opening a new plant in a different country and closing one production plant in home country. The investment decisions of the firms determine the industry structure. The national governments of the two countries then choose their trade and environmental policies. Finally, after policies have been chosen, firms decide how much to produce and abate emissions in each plant. This timing assumption is made to capture the idea that decisions on investing in production capacity occur less frequently than decisions on taxes and subsidies or output and abatement.

[9]If the plant-level fixed cost is low, the firms would want to open production plants in their home country or abroad due to convex production costs. Here, we want to concentrate on how national policy design influences the firms' strategies under the two international regimes. Therefore, we take the number of production plants as given.

3 Output, Abatement, and Policy Choices

In this section, we determine the output and abatement decisions of the firms and the policy decisions of the governments under the different industry structures. We begin by considering the profit maximization problem of the firms and then analyze policy design under the two regimes.

3.1 Output and Abatement Choices

Given the industry structure and the policies chosen by the national governments, the two firms choose output and abatement levels in their two plants so as to maximize profits. Profit of firm i is denoted by π^i. Profit maximization problem of firm i is

$$\max_{x^i, x^{*i}, q^i, q^{*i}} \left\{ \pi^i = p\left(Y\right) y^i - C^i\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) \right\}$$

where C^i is determined by equation (1).

Assuming interior solutions, first-order conditions for profit maximization for firm i are[10]

$$\frac{\partial \pi^i}{\partial x^i} = p'\left(Y\right) y^i + p\left(Y\right) - C^i_{x^i}\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) = 0, \tag{2}$$

$$\frac{\partial \pi^i}{\partial x^{*i}} = p'\left(Y\right) y^i + p\left(Y\right) - C^i_{x^{*i}}\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) = 0, \tag{3}$$

$$\frac{\partial \pi^i}{\partial q^i} = C^i_{q^i}\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) = 0, \tag{4}$$

$$\frac{\partial \pi^i}{\partial q^{*i}} = C^i_{q^{*i}}\left(\mathbf{u}; x^i, x^{*i}, q^i, q^{*i}; j\right) = 0. \tag{5}$$

Conditions (2) and (3) imply that profit maximizing output level in each plant is such that marginal revenue equals marginal cost of production. Conditions (4) and (5) in turn require that marginal abatement cost in each plant equals the emission tax rate in the country where the plant is located.

We denote the profit maximizing output levels as a function of the policies and industry structure by $y^i\left(\mathbf{u}; j\right)$. Corresponding maximum profits are denoted by $\pi^i\left(\mathbf{u}; j\right)$.

[10] Derivatives of functions of one variable are denoted by primes. Partial derivatives of functions of several variables are denoted by subscripts.

From the first-order conditions for profit maximization we can derive the following comparative statics results:

$$y_t^H(\mathbf{u}; j) < 0 \text{ for } j = nn, mm, nm,$$

and

$$y_t^F(\mathbf{u}; nn) > 0,\ y_t^F(\mathbf{u}; mm) < 0, \text{ and } y_t^F(\mathbf{u}; nm) < 0.$$

Regardless of the industry structure, stricter emission control in home country increases the production costs of home firm. Therefore, when emission tax rate is increased in home country, home firm reduces supply. However, the reaction of foreign firm depends on the industry structure. When foreign firm is national, its production costs are not affected by the policy change, and foreign firm increases supply as a reaction to reduced supply by the rival firm. When foreign firm is multinational, its production costs in the plant that is located in home country increase. As a result, it reduces output in the plant located in home country and increases output in the plant located in foreign country. Its overall output declines.

In the same manner, we have that

$$y_s^H(\mathbf{u}; j) > 0 \text{ and } y_s^F(\mathbf{u}; j) < 0 \text{ for } j = nn, mm, nm.$$

Regardless of the industry structure, a higher export subsidy in home country reduces the production costs of home firm and induces it to expand output. As a result, foreign firm cuts down on supply.

3.2 Policy Design

We now turn to analyze policy design under the two international regimes. Under both regimes, each government chooses its policies in order to maximize domestic aggregate welfare and takes the policies chosen by the other government and the equilibrium behavior of the firms as given.[11] In order to study policies when at least one firm is

[11] We study only non-cooperative policy design. Because the firms have market power, the non-cooperative policy design need not be efficient. Coordination of environmental policies when polluting firms are multinational is studied in the second essay of this dissertation.

multinational, the ownership structure of multinational firms must be specified. For simplicity, we assume that the ownership structure of a firm remains unchanged when it invests abroad. Thus, when home firm opens a plant in foreign country, ownership of the firm remains entirely in home country.

We first analyze policy design when the governments are free to use both environmental and trade policy. We then consider a trade agreement regime where the governments are constrained not to use export subsidies. Unless the industry structure is asymmetric, the policy design problems of the two governments are symmetric. We will therefore mainly focus on home government.

3.2.1 Regime of trade and environmental policy

In each country, domestic aggregate welfare consists of profits for domestic shareholders, tax revenue net of export subsidies, and environmental damage caused by emissions. We denote domestic aggregate welfare in home country by w and in foreign country by w^*. Thus, home government chooses t and s so as to maximize

$$w(\mathbf{u};j) = \pi^H(\mathbf{u};j) + tE(\mathbf{u};j) - sy^H(\mathbf{u};j) - d(E(\mathbf{u};j)),$$

and foreign government chooses t^* and s^* so as to maximize

$$w^*(\mathbf{u};j) = \pi^F(\mathbf{u};j) + t^*E^*(\mathbf{u};j) - s^*y^F(\mathbf{u};j) - d(E^*(\mathbf{u};j)),$$

where $E(\mathbf{u};j)$ and $E^*(\mathbf{u};j)$ are emission levels in home and foreign country.

The first-order conditions for welfare maximization for home government are

$$\pi_t^H(\mathbf{u};j) + E(\mathbf{u};j) + tE_t(\mathbf{u};j) - sy_t^H(\mathbf{u};j) - d'(E(\mathbf{u};j))E_t(\mathbf{u};j) = 0 \qquad (6)$$

and

$$\pi_s^H(\mathbf{u};j) + tE_s(\mathbf{u};j) - sy_s^H(\mathbf{u};j) - y^H(\mathbf{u};j) - d'(E(\mathbf{u};j))E_s(\mathbf{u};j) = 0, \qquad (7)$$

where the first term denotes the effect of a policy change on profits of the domestic firm. The three following terms refer to changes in tax revenue net of subsidies to the domestic firm. The last term is the welfare-effect of a change in emissions. The first-order conditions for foreign government are analogous.

Under the assumption that the second-order conditions are satisfied, these first-order conditions implicitly determine a unique equilibrium emission tax policy and subsidy policy for each government. We denote these equilibrium policies under industry structure j by $\mathbf{u}^j = (t^j, t^{*j}, s^j, s^{*j})$. Results on policy design under the different industry structures are summarized as

Lemma 1 *When the governments can freely design both trade and environmental policy and both firms are national, each government sets the emission tax rate so that the negative effect of emissions is fully internalized and give export subsidies to the domestic producer. When at least one firm is multinational, the government of the host country of the investment sets an emission tax rate that exceeds the marginal damage of emissions and gives export subsidies to the domestic firm.*

Proof. See Appendix A. ■

Environmental policy is not an efficient way of influencing the market share and profits of the domestic firm as lowering environmental standards yields a cost in terms of increased environmental damage. An export subsidy, in contrast, can be efficiently used to enhance the competitiveness of the domestic producer. Therefore, when possible, the governments use environmental policy to correct the negative externality caused by production and the export subsidy to increase profits of domestic shareholders.

When one or both firms are multinational, in at least one country, there is a production plant that is owned by foreign shareholders. The government of the host country of this affiliate ignores the profits accruing to foreign shareholders when choosing policies. As the governments cannot discriminate between the firms in terms of environmental regulation, they set emission tax rates above the level of full internalization of environmental damage and then compensate the domestic shareholders by giving an export subsidy.

3.2.2 Trade Agreement Regime

We now turn to the trade agreement regime. The interpretation of the trade agreement is that national governments cannot use export subsidies for domestic producers and are thus restricted to set $s = 0$ and $s^* = 0$. We denote the restricted policy vector by $\widehat{\mathbf{u}} = (t, t^*, 0, 0)$.

Under the trade agreement regime, home government chooses t so as to maximize

$$w\left(\widehat{\mathbf{u}};j\right)=\pi^{H}\left(\widehat{\mathbf{u}};j\right)+tE\left(\widehat{\mathbf{u}};j\right)-d\left(E\left(\widehat{\mathbf{u}};j\right)\right),$$

and foreign government chooses t^{*} so as to maximize

$$w^{*}\left(\widehat{\mathbf{u}};j\right)=\pi^{F}\left(\widehat{\mathbf{u}};j\right)+t^{*}E^{*}\left(\widehat{\mathbf{u}};j\right)-d\left(E^{*}\left(\widehat{\mathbf{u}};j\right)\right),$$

where $E\left(\widehat{\mathbf{u}};j\right)$ and $E^{*}\left(\widehat{\mathbf{u}};j\right)$ are emission levels in home and foreign country.

The first-order condition for welfare maximization for home government is then

$$\pi_{t}^{H}\left(\widehat{\mathbf{u}};j\right)+E\left(\widehat{\mathbf{u}};j\right)+\left(t-d'\left(E\left(\widehat{\mathbf{u}};j\right)\right)\right)E_{t}\left(\widehat{\mathbf{u}};j\right)=0. \tag{8}$$

First-order condition for foreign government is again analogous. Under the assumption that the second-order conditions are satisfied, the first-order conditions determine unique equilibrium tax rates, which we denote by $\widehat{\mathbf{u}}^{j}=\left(\widehat{t}^{j},\widehat{t^{*}}^{j},0,0\right)$.

As under the first regime, we are interested in policy design under the different industry structures given equilibrium behavior of the firms. We summarize the results as

Lemma 2 *Under the trade agreement regime, the emission tax rates are lower than the marginal damage of emissions when both firms are national. When both firms are multinational, tax rates in both countries exceed marginal damage. When only one firm is multinational, tax rate exceeds marginal damage in the host country of the affiliate of the multinational firm and is lower than marginal damage in the home country of the multinational firm.*

Proof. See Appendix A. ■

The reason for these results is twofold. First, when the firms are national, lowering emission tax rate enhances the competitiveness of the domestic firm. This effect has an important role in policy design as profits accruing to domestic shareholders constitute part of the domestic aggregate welfare that each government seeks to maximize. In contrast, when the firms are multinational, relaxing environmental control induces both firms to increase output. Therefore, changes in environmental policy do not influence the market share of the domestic producer and consequently environmental policy is not useful in favoring the shareholders of the domestic firm. Second, when the polluting firms are multinational each government has an incentive to tighten pollution control in order to tax profits accruing to foreign owners of the multinational firms.

4 Equilibrium Industry Structure

We now determine the equilibrium industry structure. Each firm faces a decision whether to remain national or to open a new production plant abroad. When taking this decision, the firms take into account what kind of policies will be chosen by the governments under each industry structure and what the corresponding profits will be.

In order to able to compare profits under the different industry structures, we assume that

Assumption 3 *Demand is* $p(Y) = A - Y$, *where* $A > 0$, *and cost functions are* $c(x) = \frac{1}{2}x^2$, $g(q) = \frac{1}{2}q^2$, *and* $d(E) = \frac{1}{2}dE^2$.

By these assumptions the model becomes fully parametrized and provides closed form solutions. In order to keep the presentation clear, we locate the solutions for optimal output and abatement levels as a function of the policies together with the equilibrium policies in Appendix B.

The two strategies available to the firms are to invest abroad and to remain national. We represent all costs related to opening a new plant abroad and closing one plant in firm's initial home country by a fixed investment cost, G. If the firms do not have a dominant strategy, we have three Nash equilibria, two in pure strategies and one in mixed strategies. In that case, we will concentrate on the mixed strategy equilibrium. The mixed strategy equilibrium can be thought of as describing the tendency towards multinationalization. When focusing on mixed strategies, it is possible to analyze in a tractable way, how changes in the parameters of the model influence the attractiveness of investing abroad.

In order to facilitate the discussion of the results, we define Δ^n and Δ^m to be the gain in operating profits from investment under the regime of trade and environmental policy when the rival firm is national and multinational, respectively. Thus

$$\Delta^n = \pi^H(\mathbf{u}^{mn}; mn) - \pi^H(\mathbf{u}^{nn}; nn) = \pi^F(\mathbf{u}^{nm}; nm) - \pi^F(\mathbf{u}^{nn}; nn)$$

and

$$\Delta^m = \pi^H(\mathbf{u}^{mm}; mm) - \pi^H(\mathbf{u}^{nm}; nm) = \pi^F(\mathbf{u}^{mm}; mm) - \pi^F(\mathbf{u}^{mn}; mn).$$

Under the trade agreement regime, we denote this gain by $\widehat{\Delta}^n$ and $\widehat{\Delta}^m$. We analyze the equilibrium profits and location choices of the firms first under the regime where both environmental and trade policy can be used and then under the trade agreement regime.

4.1 Regime of trade and environmental policy

We first determine how investing abroad influences the operating profits of the firms. By using the equilibrium policies and corresponding supply and abatement strategies of the firms, we can show that there exist cut-off values $\underline{d}$ and $\overline{d}$ for the environmental damage parameter, such that the following relationships hold:

$$\begin{aligned} \Delta^m &< 0 \text{ for all } d > 0, \\ \Delta^n &> 0 \text{ if } d \in \left(\underline{d}, \overline{d}\right) \text{ and} \\ \Delta^n &< 0 \text{ if } d < \underline{d} \text{ and } d > \overline{d}. \end{aligned}$$

The first inequality implies that it is never profitable to invest abroad if the rival firm is multinational. The following two inequalities state that when the rival firm is national, investment abroad increases operating profits under certain values for the environmental damage parameter.

Figure 1 illustrates these relations. It shows the relative change in profits when investing abroad when the rival firm is national and multinational. This relative change is independent of the size of the export market, determined by parameter A in the demand function.

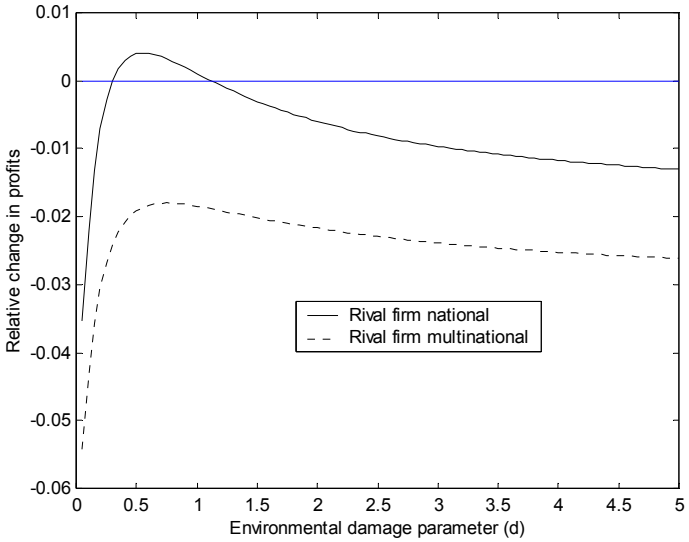

Figure 1. Relative change in profits when investing abroad under the regime of trade and environmental policy.

If foreign firm invests in home country while home firm remains national the following policy changes occur. First, the government of home country uses emission taxation both to control emissions and to tax profits of foreign shareholders. When d is small, the latter incentive dominates and investment induces a large increase in emission tax rate. If d is higher, the relative incentive to tax foreign shareholders is less important compared to the incentive to control emissions, and the reaction of emission tax rate to investment is more modest. Second, home government increases the export subsidy for the domestic firm. The increase in export subsidy due to investment is large when d is small. This suggests that the aim of this policy change is to compensate the domestic shareholders for the negative effect of stricter emission taxation.

Lemma 3 *When the governments can use both trade and environmental policy, investing abroad is never a dominant strategy.*

Proof. Straightforward since $\Delta^m < 0$ for all $d > 0$ and $A > 0$. ■

This implies that when $d \notin \left(\underline{d}, \overline{d}\right)$ both firms remain national regardless of the strategy adopted by the rival firm. A necessary condition for at least one firm to invest

abroad is therefore $d \in \left(\underline{d}, \overline{d}\right)$. However, even if investment abroad increases operating profits, it may still be in the interest of the firms to remain national. This of course happens if the fixed cost of investment is too high, i.e. if $\Delta^n < G$. The following proposition characterizes the situation where there are potential gains from investing abroad, that is, $d \in \left(\underline{d}, \overline{d}\right)$ and G is low enough.

Proposition 1 *If $\Delta^n > G$, there exists a mixed strategy equilibrium where both firms remain national with probability β. This probability is increasing in G and decreasing in A and is always strictly larger than $\frac{1}{2}$.*

Proof. Assume that one firm remains national with probability β. Then the rival firm is indifferent between investing abroad and remaining national if

$$\beta = \frac{\Delta^m - G}{\Delta^m - \Delta^n},$$

where $\Delta^m < 0$ and $\Delta^n > 0$. Thus $\Delta^n > G \Rightarrow \beta < 1$. As the firms are symmetric there is a mixed strategy equilibrium where the firms remain national with probability β. The gain from investment, Δ^m and Δ^n, can be rewritten so that $\Delta^m = A\widetilde{\Delta}^m$ and $\Delta^n = A\widetilde{\Delta}^n$ where $\widetilde{\Delta}^m$ and $\widetilde{\Delta}^n$ are independent of A. Then,

$$\frac{\partial \beta}{\partial G} = -\frac{1}{\Delta^m - \Delta^n} > 0 \text{ and } \frac{\partial \beta}{\partial A} = \frac{G\left(\widetilde{\Delta}^m - \widetilde{\Delta}^n\right)}{\left(\Delta^m - \Delta^n\right)^2} < 0.$$

It is straightforward to show that $\Delta^n > 0$ implies that $|\Delta^m| > |\Delta^n|$. Assume that $G = 0$. Then

$$\beta = \frac{\Delta^m}{\Delta^m - \Delta^n} > \frac{1}{2}.$$

■

It is intuitive that investing abroad is more attractive when G is small. Firms are also more likely to invest abroad when the size of the export market, represented by parameter A, increases. The larger the export market, the bigger the gain in operating profits when investing abroad, which reduces the relative importance of the cost of investment. However, even in the extreme case where $G = 0$, each firm is more likely to remain national than to invest abroad.

When the firms are national, each government uses the emission tax to correct the negative externality generated by production and the export subsidy to increase the profits of the domestic shareholders. Assume then that foreign firm invests in home country. This investment induces home government to set a higher emission tax rate in order to tax part of the profits accruing to foreign shareholders. Consequently, profits generated by the plant that is moved from foreign country to home country decrease compared to the situation where both plants remain in foreign country. Foreign government in turn lowers its emission tax rate and as a result the profits generated by the plant that remains in foreign country increase. However, when home government tightens emission taxation it also increases the export subsidy in order to compensate the negative effect of a higher emission tax rate on the domestic firm. This mitigates the positive effect of a higher emission tax rate in home country and lower tax rate in foreign country on the market share of foreign firm and thereby reduces the profitability of the investment. Due to this effect, in general, the increase in profits generated by the plant that remains in foreign country is not large enough to offset the costs related to the investment.

4.2 Trade Agreement Regime

We now turn to the regime where the governments are restricted not to use trade policy. As under the first regime we can establish the following relationships:

$$\begin{aligned} \widehat{\Delta}^m &> 0 \text{ for all } d > 0, \\ \widehat{\Delta}^n &> 0 \text{ if } d > \widehat{d} \text{ and} \\ \widehat{\Delta}^n &< 0 \text{ if } d < \widehat{d}. \end{aligned}$$

The first inequality implies that investment abroad always increases operating profits when the rival firm is multinational. The following two inequalities state that when the rival firm is national, for low values of the environmental damage parameter, d, investment abroad lowers profits whereas for higher values it always increases profits. As under the first regime, the size of the export market affects the absolute but not the relative change in operating profits when investing abroad. Figure 2 below shows this relative change under the trade agreement regime.

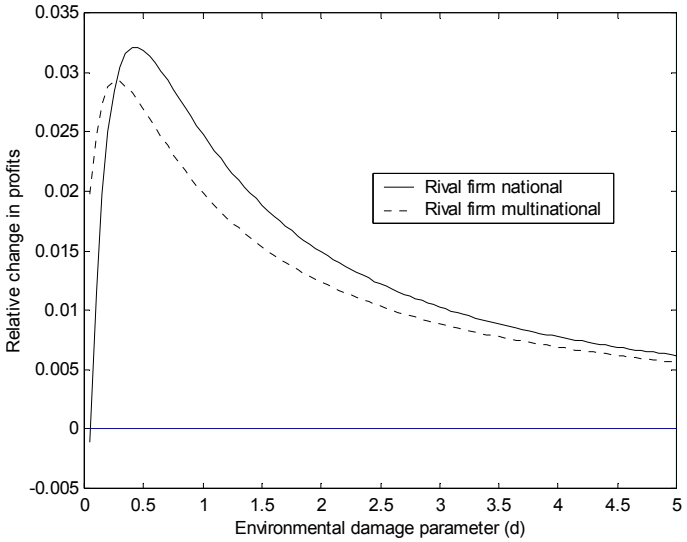

Figure 2. Relative change in profits when investing abroad under the trade agreement regime.

Consider again the event that foreign firm invests in home country. Then emission taxation in home country is partly destined to tax foreign shareholders and partly to control emissions. When d is small, the first effect is relatively more important and investment to home country induces a large increase in tax rate. Except for very small values of environmental damage, the investment is profitable as the domestic firm reacts by reducing supply. When the environmental damage caused by emissions is very small and both firms are national, the governments actually set negative emission tax rates. In that situation investing abroad would trigger policy changes that are not favorable to the investing firm.[12]

Again, it may be the case that the fixed cost of investment is high enough to deter all investment and each firm prefers to remain national regardless of what the rival firms does. However,

[12] We do not require the equilibrium emission tax rates to be non-negative. An alternative assumption would be that zero is the lower bound for emission tax rates, as under the trade agreement regime negative emission tax rates could well be prohibited. This assumption would make remaining national less profitable under the trade agreement regime.

Lemma 4 *When the governments can use only environmental policy and $d > \widehat{d}$, investing abroad is a dominant strategy for both firms if the fixed cost of investment is low enough.*

Proof. Straightforward, since $d > \widehat{d}$ implies that $\widehat{\Delta}^n > 0$ for all $A > 0$. Since $\widehat{\Delta}^m > 0$ for all $d > 0$ and $A > 0$, there exist values of $G > 0$ such that $\widehat{\Delta}^n > G$ and $\widehat{\Delta}^m > G$. ■

When both firms are national, the governments use environmental policy not only to correct the negative externality caused by production but also to achieve trade policy goals. By Lemma 2, emission tax rates in both countries are lower than the marginal damage caused by emissions. Assume that in this situation foreign firm invests in home country. As a result, the national governments of the two countries will choose different emission tax policies. In particular, home government will set a tax rate that exceeds the marginal damage of emissions whereas the tax rate set by foreign government will be lower than the marginal damage of emissions. There are two reasons for this. First, in choosing its policy, home government ignores profits accruing to foreign shareholders. Second, from the point of view of home government, relaxing environmental policy is no longer useful in shifting profits to the domestic firm as adopting a more lax environmental policy induces foreign firm to expand supply. For foreign firm the motive to invest abroad is purely strategic: the profits generated by the plant that is moved to home country decrease. However, by investing in home country foreign firm is able to influence the policy choices of home government and thus supply decisions of home firm in a way that leads to increased profits generated by the plant that remains in foreign country. Figure 2 shows that except for very low values of the environmental damage parameter this positive effect dominates.

We are now able to compare the incentives of the firms to invest abroad under the two regimes. The previous discussion is summarized in the following proposition:

Proposition 2 *Emergence of multinational firms is more likely when the governments are constrained not to use direct trade policy measures.*

Proof. By using $\widehat{\Delta}^n$, $\widehat{\Delta}^m$, and Δ^n derived in Appendix C we can show that

$$\widehat{\Delta}^n > \Delta^n \text{ and } \widehat{\Delta}^m > \Delta^n \text{ for all } A > 0 \text{ and } d > 0.$$

Therefore,

$$\Delta^n > G \Longrightarrow \widehat{\Delta}^n > G \text{ and } \widehat{\Delta}^m > G.$$

■

The gain in operating profits when investing abroad is always higher under the trade agreement regime than under the regime of both environmental and trade policy. Therefore, if the firms remain national with probability $\beta \in \left(\frac{1}{2}, 1\right)$ under the regime of both environmental and trade policy, they have a dominant strategy to invest abroad under the trade agreement regime. Therefore, under a certain parameter range, signing an agreement that leads to the trade agreement regime, increases the probability that polluting firms invest abroad.

Here, investment flows are between home and foreign country while the consumers are located in the third country. Consequently, adding strictly positive transportation costs would not affect the firms' incentives to invest abroad. If, instead, the product of the firms was consumed in home and foreign country, transportation costs could be avoided by investing abroad. In that situation, an increase in transportation costs would clearly increase the attractiveness of investing abroad. However, if the transportation costs do not depend on the international institutional setting, they would affect the incentives to invest abroad in the same way under the two regimes. Therefore, if the transportation costs are very high and the fixed cost of investment sufficiently low, the firms may invest abroad regardless of the government policies in a setting of domestic consumption.

What is crucial for Proposition 2 is the different nature of the two instruments available for the national governments. The governments cannot differentiate the treatment of emissions generated by production plants according to their ownership. Therefore, environmental policy cannot be used to discriminate between the firms when they are multinational. In contrast, export subsidies can be efficiently targeted to the domestic firm. This means that the relationship of each government and the domestic firm depends on the international regime. When the government cannot use trade policy to protect the domestic firm, it will use an instrument that attracts investment from the foreign firm.

5 Conclusions

We have studied the influence of international trade agreements on the location strategies of polluting firms. Our focus has been on the indirect effects of these agreements through changes in the design of national environmental policies. Our main result is that a change in the international regime that restricts the instrument set available to the national governments may lead to multinationalization of production.

Under the trade agreement regime, firms invest abroad because they want to influence the policy decisions of the other government and output decisions of the rival firm. When the firms are national, governments use environmental policy not only to correct the negative externality caused by production but also to shift profits to the domestic shareholders. In this situation, foreign owned plants not only eliminate the possibility to use lax environmental policy to trade related goals but also create an incentive to tax profits accruing to foreign shareholders. This induces the government to tighten emission control which in turn leads to lower market share for the domestic producer.

In contrast, when the governments may use both environmental and trade policy, investment abroad does not have the same strategic effect. When both firms are national, emission tax rates equal the marginal damage caused by emissions and firms receive export subsidies. The fact that the governments have two instruments at their disposal and can use export subsidies to discriminate between the firms, makes investment abroad less attractive for the firms. If the foreign firm invests in home country, home government raises the emission tax rate above the marginal damage of emissions in order to capture part of the profits accruing to the foreign shareholders. However, at the same time it also raises the export subsidy to the domestic firm so as to compensate the domestic shareholders for the negative effects of stricter emission taxation. This makes investment abroad less profitable.

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A Appendix

For the sake of notational clarity, we define $z^{H,u}(\mathbf{u};j)$ and $z^{F,u}(\mathbf{u};j)$ to be the price effect of a change in policy variable $u \in \{t, t^*, s, s^*\}$ on the profit of home and foreign firm, respectively, under industry structure j. Then

$$\begin{aligned} z^{H,u}(\mathbf{u};j) &= p'(Y(\mathbf{u};j))\, y_u^F(\mathbf{u};j)\, y^H(\mathbf{u};j), \\ z^{F,u}(\mathbf{u};j) &= p'(Y(\mathbf{u};j))\, y_u^H(\mathbf{u};j)\, y^F(\mathbf{u};j). \end{aligned}$$

Proof of Lemma 1. When the firms are national, equations (6) and (7) become

$$z^{H,t} - s^{nn} y_t^H + (t^{nn} - d'(E))\, E_t = 0 \tag{A1}$$

and

$$z^{H,s} - s^{nn} y_s^H + (t^{nn} - d'(E))\, E_s = 0, \tag{A2}$$

where all functions and partial derivatives are evaluated at $(\mathbf{u}^{nn}; nn)$. As $z^{H,t}(\mathbf{u}^{nn}; nn) = -z^{H,s}(\mathbf{u}^{nn}; nn)$ and $y_t^H(\mathbf{u}^{nn}; nn) = -y_s^H(\mathbf{u}^{nn}; nn)$, it follows that $t^{nn} = d'(E)$ and $s^{nn} > 0$.

When both firms have one production plant in each country, (6) and (7) become

$$z^{H,t} - s^{mm} y_t^H + (t^{mm} - d'(E))\, E_t + \left(x^F - t^{mm}\right) = 0 \tag{A3}$$

and

$$z^{H,s} - s^{mm} y_s^H + (t^{mm} - d'(E))\, E_s = 0, \tag{A4}$$

where all functions and derivatives are evaluated at $(\mathbf{u}^{mm}; mm)$. Solving (A4) for s^{mm} and plugging into (A3) gives

$$z^{H,t} y_s^H - (t^{mm} - d'(E))\left(E_s y_t^H - E_t y_s^H\right) - z^{H,s} y_t^H + \left(x^F - t^{mm}\right) y_s^H = 0.$$

Solving for $(t^{mm} - d'(E))$ yields

$$(t^{mm} - d'(E)) = \frac{z^{H,t} y_s^H - z^{H,s} y_t^H + \left(x^F - t^{mm}\right) y_s^H}{E_s y_t^H - E_t y_s^H}.$$

The nominator is positive since $z^{H,t}(\mathbf{u};mm) > 0$ and $z^{H,s}(\mathbf{u};mm) > 0$ and $y_s^H(\mathbf{u};mm) > 0$ and $y_t^H(\mathbf{u};mm) < 0$. The denominator is also positive since $\left|y_t^H(\mathbf{u};mm)\right| < \left|y_s^H(\mathbf{u};mm)\right|$ and $|E_s(\mathbf{u};mm)| < |E_t(\mathbf{u};mm)|$. Since $(t^{mm} - d'(E(\mathbf{u};mm))) > 0$ it directly follows from (A4) that $s^{mm} > 0$.

Finally, when foreign firm is multinational and home firm is national, (6) and (7) become

$$z^{H,t} - s^{nm}y_t^H + (t^{nm} - d'(E))E_t + \left(x^F - t^{nm}\right) = 0 \tag{A5}$$

and

$$z^{H,s} - s^{nm}y_s^H + (t^{nm} - d'(E))E_s = 0, \tag{A6}$$

where all functions and derivatives are evaluated at $(\mathbf{u}^{nm};nm)$. From profit maximization it follows that $y_t^H(\mathbf{u};nm) < 0$, $y_s^H(\mathbf{u};nm) > 0$, $y_t^F(\mathbf{u};nm) < 0$, $y_s^F(\mathbf{u};nm) < 0$. Hence, $z^{H,t}(\mathbf{u};nm) > 0$, $z^{H,s}(\mathbf{u};nm) > 0$. Solving (A6) for s^{nm} and plugging into (A5), it can be rewritten as

$$(t^{nm} - d'(E)) = \frac{z^{H,t}y_s^H - z^{H,s}y_t^H + \left(x^F - t^{nm}\right)y_s^H}{y_s^H y_t^H\left(\frac{E_s}{y_s^H} - \frac{E_t}{y_t^H}\right)},$$

where the RHS is positive since $\left(\frac{E_s}{y_s^H} - \frac{E_t}{y_t^H}\right) < 0$ as

$$\begin{aligned} \frac{E_t}{y_t^H} &= \frac{x_t^H - q_t^H + x_t^{*H} - q_t^{*H} + x_t^F - q_t^F}{x_t^H + x_t^{*H}} > 1 \text{ and} \\ 0 &< \frac{E_s}{y_s^H} = \frac{x_s^H + x_s^{*H} + x_s^F}{x_s^H + x_s^{*H}} < 1. \end{aligned}$$

Since $(t^{nm} - d'(E)) > 0$ it follows that $s^{nm} > 0$. ■

Proof of Lemma 2. When the firms are national, (8) becomes

$$z^{H,t}(\widehat{\mathbf{u}};nn) + \left(\widehat{t}^{nn} - d'(E(\widehat{\mathbf{u}};nn))\right)E_t(\widehat{\mathbf{u}};nn) = 0. \tag{A7}$$

Since $z^{H,t}(\widehat{\mathbf{u}};nn) < 0$ and $E_t(\widehat{\mathbf{u}};nn) < 0$ it directly follows that $\widehat{t}^{nn} < d'(E(\widehat{\mathbf{u}};nn))$.

When the firms are multinational, (8) becomes

$$z^{H,t}(\widehat{\mathbf{u}};mm) + \left(\widehat{t}^{mm} - d'(E(\widehat{\mathbf{u}};mm))\right)E_t(\widehat{\mathbf{u}};mm) + \left(x^F(\widehat{\mathbf{u}};mm) - \widehat{t}^{mm}\right) = 0. \tag{A8}$$

As $z^{H,t}(\widehat{\mathbf{u}};mm) > 0$, $\left(x^F(\widehat{\mathbf{u}};mm) - \widehat{t}^{mm}\right) > 0$ and $E_t(\widehat{\mathbf{u}};mm) < 0$ we have that $\widehat{t}^{mm} > d'(E(\widehat{\mathbf{u}};mm))$.

Finally, when foreign firm is multinational and home firm is national, the first-order conditions of the governments are

$$z^{H,t}(\widehat{\mathbf{u}};nm) + \left(\widehat{t}^{nm} - d'(E(\widehat{\mathbf{u}};nm))\right) E_t(\widehat{\mathbf{u}};nm) + \left(x^F(\widehat{\mathbf{u}};nm) - \widehat{t}^{nm}\right) = 0 \tag{A9}$$

and

$$z^{F,t^*}(\widehat{\mathbf{u}};nm) + \left(\widehat{t^*}^{nm} - d'(E^*(\widehat{\mathbf{u}};nm))\right) E^*_{t^*}(\widehat{\mathbf{u}};nm) = 0. \tag{A10}$$

Again $E_t(\widehat{\mathbf{u}};nm) < 0$ and $E^*_{t^*}(\widehat{\mathbf{u}};nm) < 0$. Since $z^{H,t}(\widehat{\mathbf{u}};nm) > 0$ and $z^{F,t^*}(\widehat{\mathbf{u}};nm) < 0$, we have that $\widehat{t}^{nm} > d'(E(\widehat{\mathbf{u}};nm))$ and $\widehat{t^*}^{nm} < d'(E^*(\widehat{\mathbf{u}};nm))$. ■

B Equilibrium output, abatement, and policies under Assumption 3

Under Assumption 3, using first-order conditions (2)-(5) and the corresponding first-order conditions of foreign firm yields

$$x^H(\mathbf{u};nn) = x^{*H}(\mathbf{u};nn) = \frac{1}{7}A + \frac{5}{21}s - \frac{5}{21}t + \frac{2}{21}t^* - \frac{2}{21}s^*, \tag{B1}$$

$$x^F(\mathbf{u};nn) = x^{*F}(\mathbf{u};nn) = \frac{1}{7}A + \frac{5}{21}s^* - \frac{5}{21}t^* + \frac{2}{21}t - \frac{2}{21}s, \tag{B2}$$

$$E(\mathbf{u};nn) = \frac{2}{7}A + \frac{10}{21}s - \frac{52}{21}t - \frac{4}{21}s^* + \frac{4}{21}t^*, \tag{B3}$$

$$E^*(\mathbf{u};nn) = \frac{2}{7}A + \frac{10}{21}s^* - \frac{52}{21}\tau - \frac{4}{21}s + \frac{4}{21}t, \tag{B4}$$

and profits for home firm are

$$\pi^H(\mathbf{u};nn) = \frac{5}{2}\left(x^H(\mathbf{u};nn)^2 + x^{*H}(\mathbf{u};nn)^2\right) + t^2. \tag{B5}$$

In the same manner when $j = mm$,

$$x^H(\mathbf{u}; mm) = \frac{1}{7}A + \frac{5}{21}s - \frac{4}{7}t - \frac{2}{21}s^* + \frac{3}{7}t^*, \tag{B6}$$

$$x^F(\mathbf{u}; mm) = \frac{1}{7}A + \frac{5}{21}s^* - \frac{4}{7}t - \frac{2}{21}s + \frac{3}{7}t^*, \tag{B7}$$

$$x^{*H}(\mathbf{u}; mm) = \frac{1}{7}A + \frac{5}{21}s - \frac{4}{7}t^* - \frac{2}{21}s^* + \frac{3}{7}t, \tag{B8}$$

$$x^{*F}(\mathbf{u}; mm) = \frac{1}{7}A + \frac{5}{21}s^* - \frac{4}{7}t^* - \frac{2}{21}s + \frac{3}{7}t, \tag{B9}$$

$$E(\mathbf{u}; mm) = \frac{2}{7}A - \frac{22}{7}t + \frac{6}{7}t^* + \frac{3}{21}s + \frac{3}{21}s^*, \tag{B10}$$

$$E^*(\mathbf{u}; mm) = \frac{2}{7}A + \frac{6}{7}t - \frac{22}{7}t^* + \frac{3}{21}s + \frac{3}{21}s^*, \tag{B11}$$

and profits for home firm are

$$\pi^H(\mathbf{u}; mm) = \left(\frac{3}{2}x^H(\mathbf{u}; mm) + x^{*H}(\mathbf{u}; mm)\right)x^H(\mathbf{u}; mm) + \frac{1}{2}t^2 + \left(\frac{3}{2}x^{*H}(\mathbf{u}; mm) + x^H(\mathbf{u}; mm)\right)x^{*H}(\mathbf{u}; mm) + \frac{1}{2}t^{*2}. \tag{B12}$$

Finally, when $j = nm$,

$$x^H(\mathbf{u}; nm) = x^{*H}(\mathbf{u}; nm) = \frac{1}{7}A - \frac{4}{21}t + \frac{1}{21}t^* - \frac{2}{21}s^* + \frac{5}{21}s, \tag{B13}$$

$$x^F(\mathbf{u}; nm) = \frac{1}{7}A - \frac{11}{21}t + \frac{8}{21}t^* + \frac{5}{21}s^* - \frac{2}{21}s, \tag{B14}$$

$$x^{*F}(\mathbf{u}; nm) = \frac{1}{7}A + \frac{10}{21}t - \frac{13}{21}t^* + \frac{5}{21}s^* - \frac{2}{21}s, \tag{B15}$$

$$E(\mathbf{u}; nm) = \frac{3}{7}A - \frac{82}{21}t + \frac{10}{21}t^* + \frac{1}{21}s^* + \frac{8}{21}s, \tag{B16}$$

$$E^*(\mathbf{u}; nm) = \frac{1}{7}A + \frac{10}{21}t - \frac{34}{21}t^* + \frac{5}{21}s^* - \frac{2}{21}s, \tag{B17}$$

and profits for home and foreign firm are

$$\pi^H(\mathbf{u}; nm) = \frac{5}{2}\left(x^H(\mathbf{u}; nm)^2 + x^{*H}(\mathbf{u}; nm)^2\right) + t^2. \tag{B18}$$

and

$$\pi^F(\mathbf{u}; nm) = \left(\frac{3}{2}x^F(\mathbf{u}; nm) + x^{*F}(\mathbf{u}; nm)\right)x^F(\mathbf{u}; nm) + \frac{1}{2}t^2 + \left(\frac{3}{2}x^{*F}(\mathbf{u}; nm) + x^F(\mathbf{u}; nm)\right)x^{*F}(\mathbf{u}; nm) + \frac{1}{2}t^{*2}. \tag{B19}$$

B.1 Regime of trade and environmental policy

By plugging (B1)-(B4) into equations (A1), (A2) and the corresponding first-order conditions for foreign government, we have that

$$t^{nn} = t^{*nn} = 10d\frac{A}{72d+31}, \tag{B20}$$

$$s^{nn} = s^{*nn} = 4\left(2d+1\right)\frac{A}{72d+31}. \tag{B21}$$

Similarly, plugging (B6)-(B11) into equations (A3) and (A4) yields

$$t^{mm} = t^{*mm} = \frac{1}{6}A\frac{31d+7}{37d+22}, \tag{B22}$$

$$s^{mm} = s^{*mm} = \frac{1}{12}A\frac{52d+37}{37d+22}. \tag{B23}$$

Finally, plugging (B13)-(B17)) into equations (A5)-(A6) gives

$$t^{*nm} = \frac{Ad\left(282d+79\right)}{2040d^2+2002d+445}, \tag{B24}$$

$$t^{nm} = \frac{1}{4}\frac{A\left(1144d^2+774d+77\right)}{2040d^2+2002d+445}, \tag{B25}$$

$$s^{nm} = \frac{A\left(256d^2+274d+73\right)}{2040d^2+2002d+445}, \tag{B26}$$

$$s^{*nm} = \frac{1}{2}\frac{A\left(448d^2+486d+111\right)}{2040d^2+2002d+445}. \tag{B27}$$

B.2 Trade Agreement Regime

Given that $s=0$ and $s^*=0$ by plugging (B1)-(B4) into equation (A7) and the corresponding first-order condition for foreign government, we have that

$$\widehat{t}^{nn} = \widehat{t^*}^{nn} = 2A\frac{13d-1}{208d+89}. \tag{B28}$$

Similarly, plugging (B6)-(B11) into (A8) gives

$$\widehat{t}^{mm} = \widehat{t^*}^{mm} = \frac{1}{4}A\frac{44d+9}{88d+53}. \tag{B29}$$

Finally, plugging (B13)-(B17)) into (A9) and (A10) yields

$$\widehat{t}^{*nm} = \frac{1}{2}A\frac{4506d + 22304d^2 - 683}{20127 + 88702d + 89216d^2} \tag{B30}$$

and

$$\widehat{t}^{nm} = A\frac{2\left(5576d^2 + 3612d + 277\right)}{20127 + 88702d + 89216d^2}. \tag{B31}$$

C Appendix

Under the regime of trade and environmental policy, gain from investment when the rival firm is multinational is

$$\Delta^m = \pi^H\left(\mathbf{u}^{mm}; mm\right) - \pi^H\left(\mathbf{u}^{nm}; nm\right),$$

where $\pi^H\left(\mathbf{u}^{mm}; mm\right)$ follows from (B12) using (B6)-(B9), (B22), and (B23). Similarly, $\pi^H\left(\mathbf{u}^{nm}; nm\right)$ follows from (B18) using (B13)-(B15) and (B24)-(B27). Straightforward calculations show that $\Delta^m < 0$ for all $d > 0$.

Gain from investment when the rival is national is

$$\Delta^n = \pi^H\left(\mathbf{u}^{mn}; mn\right) - \pi^H\left(\mathbf{u}^{nn}; nn\right)$$

where $\pi^H\left(\mathbf{u}^{mn}; mn\right) = \pi^F\left(\mathbf{u}^{nm}; nm\right)$ follows from (B19) using equations (B13)-(B15) and (B24)-(B27). In the same manner, $\pi^H\left(\mathbf{u}^{nn}; nn\right)$ follows from (B5) using equations (B1), (B2), (B20), and (B21). Straightforward calculations show that $\Delta^n = 0$ when $d = \underline{d} \approx 0.30$ and $d = \overline{d} \approx 1.12$. Furthermore, $\Delta^n > 0$ when $d \in \left(\underline{d}, \overline{d}\right)$ and $\Delta^n < 0$ when $d \notin \left(\underline{d}, \overline{d}\right)$.

Under the trade agreement regime, gain from investment when the rival firm is national is

$$\widehat{\Delta}^n = \pi^H\left(\widehat{\mathbf{u}}^{mn}; mn\right) - \pi^H\left(\widehat{\mathbf{u}}^{nn}; nn\right)$$

where $\pi^H\left(\widehat{\mathbf{u}}^{nn}; nn\right)$ is follows from (B5) using (B1), (B2) and (B28) and $\pi^H\left(\widehat{\mathbf{u}}^{mn}; mn\right) = \pi^F\left(\widehat{\mathbf{u}}^{nm}; nm\right)$ from (B19) using equations (B13)-(B15), and (B30) and (B31). We have that $\widehat{\Delta}^n = 0$ when $d = \widehat{d} \approx 0.05$ and that $\widehat{\Delta}^n > 0$ for all $d > \widehat{d}$.

Finally, gain from investment when the rival is multinational is

$$\widehat{\Delta}^m = \pi^H\left(\widehat{\mathbf{u}}^{mm}; mm\right) - \pi^H\left(\widehat{\mathbf{u}}^{nm}; nm\right)$$

where $\pi^H\left(\widehat{\mathbf{u}}^{mm}; mm\right)$ follows from (B12) using (B6)-(B9), and (B29), and $\pi^H\left(\widehat{\mathbf{u}}^{nm}; nm\right)$ from (B18) using (B13)-(B17), (B30), and (B31). It is again straightforward to show that $\widehat{\Delta}^m > 0$ for all $d > 0$.

Using the above expressions, we have that for all $d > 0$ and $A > 0$

$$\widehat{\Delta}^n - \Delta^n > 0 \text{ and } \widehat{\Delta}^m - \Delta^n > 0.$$